Sky and TELESCOPE

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Sky and TELESCOPE

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Frank S. Hogg (1904-1951)

FRANK S. HOGG

ON New Year's Day, 1951, Dr. Frank Scott Hogg died suddenly at his home in Richmond Hill, Ont., in his 47th year. He was director of the David Dunlap Observatory and head of the department of astronomy at the University of Toronto. His sudden passing is particularly startling to those who had talked with him at the astronomical gathering at the University of Michigan last June. For some years Dr. Hogg had suffered from a serious heart ailment; at Christmas time an attack of bronchitis proved to be too great a strain.

He was born in Preston, Ont., on July 26, 1904, of parents who were among the early graduates of the University of Toronto, where he himself received a bachelor's degree in 1926. He obtained his astronomical training there under Professor C. A. Chant, and was awarded the gold medal of the Royal Astronomical Society of Canada upon his graduation.

Dr. Hogg was widely known among astronomers over the whole continent: at Harvard University, where in 1929 as holder of an Agassiz fellowship he became the first Ph.D. in astronomy; at Amherst College, where he was research associate in 1930-31; at the Dominion Astrophysical Observatory, Victoria, B. C., where he was assistant astronomer from 1931 to 1934; and at many meetings of the American Astronomical Society, where members had enjoyed his scholarship and witty fellowship.

The five years of Dr. Hogg's directorship were fruitful for the observatory. A program of measuring radial velocities of over a thousand stars had been conceived and brought to virtual conclusion during this time, and a large number of graduate students had carried out research under his personal direction in such varied fields as binary stars, spectrophotometry, variable stars, instrument design, and micrometeorites. During this time also, the graduate course in astronomy was extended to include the doctor's degree. The first doctoral thesis is being submitted this year on a research problem directed by Dr. Hogg.

He found time, apart from his teaching, observing, and directing duties at the university, to play a large part in the affairs of the Royal Astronomical Society of Canada, which had long been close to his heart. He was president during 1941 and 1942, and since 1937 he had been assistant editor of the society's *Journal* and the *Observer's Handbook*, continually accepting increasing editorial responsibility.

With Mrs. Hogg he attended the International Astronomical Union meetings in Stockholm in 1938, where he renewed acquaintance with the many European astronomers whom he knew in his student days as a Parker traveling fellow from Harvard. He was a member of three IAU commissions, and at the time of his death was chairman of the national committee for Canada for the IAU.

During World War II, Dr. Hogg served on the navigation subcommittee of the National Research Council of Canada, and he invented a two-star sextant.

Dr. Hogg is survived by his wife, Dr. Helen Sawyer Hogg, and three children, Sally, a student at the University of Toronto, and David and James in high school. Mrs. Hogg will continue with her work at the David Dunlap Observatory and in the department of astronomy, where she has long been a valued member of the staff. Dr. Hogg will also be missed seriously by the community of Richmond Hill, where he had taken a leading part in village affairs and revealed, as in all that he did, his natural unselfishness and his kindness.

JOHN F. HEARD
David Dunlap Observatory

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BACK COVER: The visible spectrum of the sun, from the Fraunhofer B line (produced by oxygen in the earth's atmosphere) in the red to the H and K lines of calcium in the violet. Representative lines of many elements in the solar reversing layer are identified. The spectrum was obtained with the 13-foot spectroheliograph of Mount Wilson Observatory. (See page 117.)

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Radio telescopes that observed the eclipse in a rainstorm. At the left is the largest, a 10-foot parabola for 64.5-cm. reception, with a double dipole feed at the focus; it is on a hand-operated altazimuth mounting. On the right is the 3.15-cm. receiver, with a 6-foot reflector.

NRL Aleutian Radio Eclipse Expedition

By John P. Hagen, Fred T. Haddock, *Naval Research Laboratory,*
and Grote Reber, *National Bureau of Standards*

During the last decade, measurements of the intensity of the radiation of the sun have been made over the radio-frequency spectrum where our atmosphere is transparent. An analysis of these measurements shows that they are a source of information concerning the activity and the nature of the sun's atmosphere.

The present state of our knowledge of the sun as a radio emitter is that the basic emission is thermal and originates in the chromosphere and corona, the longer wave lengths coming from the outer regions and the shorter wave lengths from deeper in the chromosphere. This is not because the longer waves are generated solely in the corona, but rather because the atmosphere is opaque to the longer waves somewhere in the corona, whereas for the shorter waves the corona is reasonably transparent. The opacity increases with depth, and a region deeper in the chromosphere will be opaque for centimeter waves.

The part of the atmosphere dealt with here can be considered as ionized hydrogen — a binary gas composed of electrons and protons. For such a gas the absorption coefficient will be proportional to the square of the wave length, to the square of the number density of the electrons, and inversely proportional to the 3/2 power of the temperature.

Thus, during an eclipse of the sun by the moon, the radio eclipse will be annular, but will more nearly approach a total eclipse as the wave length of observation decreases. This effect is borne out by the measured eclipse curves, as we shall note later.

Earlier work[1-4] showed that the radio measurements on the radiation from the *quiet* sun (when the sun is unusually free of sunspots and other evidences of solar activity) could be interpreted as thermal radiation from the binary gas in the sun's atmosphere only if a proper combination of density gradient and temperature gradient existed. Using the density gradient of van de Hulst and Allen for the corona and of Wildt for the chromosphere, the temperature of the chromosphere increases from the boundary temperature to 10,000° K. at a height of 10,000 kilometers above the photosphere, then rises steeply to a million degrees at 23,000 kilometers.[4] The present optical data obtained from eclipse measurements is at variance with this, requiring a chromospheric temperature of 30,000° K. at 1,500 kilometers.

If this figure is accepted, then a model of the sun's atmosphere which would also be consistent with the radio measurements would require that electron densities in the chromosphere be 1/10 those assumed from the earlier work. Since the kinetic temperature of the sun's atmosphere increases with altitude through the chromosphere and into the corona (where it reaches about a million degrees), the equivalent temperature of the sun at the radio wave lengths will increase with wave length. In addition, there will be limb brightening, which will be greatest in the centimeter wave length range and taper off for both the millimeter and the meter wave lengths.[4] It is also known that active regions generally associated with spots on the surface of the sun contribute to the radio emission in a variable manner which can be correlated to some extent with sunspot activity.[5-9]

As pointed out in the note in the September, 1950, issue of *Sky and Telescope,* page 262, a total eclipse measurement offers an excellent opportunity at centimeter wave lengths to obtain sufficient resolution in scanning the sun to evaluate the theories concerning the nature of solar radiation which depend upon our meager knowledge of the sun's atmosphere. In particular, our radio experiment was designed to determine the electron density and temperature variation throughout the chromosphere and corona.

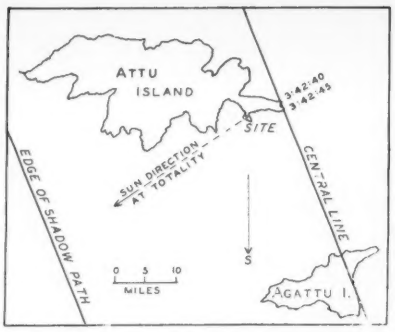
The shape of the eclipse curve for each radio frequency will differ because

of the radio brightness distribution across the solar disk, which depends upon the height in the solar atmosphere from which the radiation originates, upon the vertical temperature distribution, and upon the contribution to the total intensity by active areas such as those associated with sunspots.

The path of totality of the September 12, 1950, eclipse crossed Attu and Agattu, the two westernmost islands in the Aleutian chain. The accompanying map shows the eclipse track and the site of our observations. The path of totality was 85 miles wide, with its center crossing the easternmost tip of Attu. Since this region is rather inaccessible, a location on Alexai Point about 5.9 miles west of the center line was chosen. This location was a 10-mile drive from the Naval Aerological station, where food and lodging were available for the eclipse party of 11 men, nine from the Naval Research Laboratory and two from the National Bureau of Standards. The Aleutian Islands are noted for their bad weather, among personnel who have spent time in this region. Attu is a volcanic island with mountains rising abruptly from the sea, and low scattered clouds tend to cling to the mountainsides. Therefore, it was decided to locate on the low point of land jutting out about a mile into the ocean.

During our stay at Attu the weather was better than we had expected. Many days were either perfectly clear or with only occasional localized clouds or showers of short duration. This weather persisted until the day of the eclipse, whereupon we were hit by the tail end of the typhoon that had struck Japan two days earlier. During the eclipse there were high winds and driving rain. This did not seriously affect the data at our two longer wave lengths, but it does make the interpretation somewhat more difficult at three centimeters.

The equipment was set up on the steel matting of an abandoned air strip. On the left in the photograph is the 10-foot-



The center of the moon's shadow crossed Attu, not far from the observing site, at about 3:43 Universal time.

diameter paraboloid used at 64.5 centimeters; in the center are the two six-foot paraboloids used at 10.7 and 3.15 centimeters, and on the right the two-foot antenna for 8.5 millimeters. Attached to the mount of the latter is a photocell device for automatically recording the intensity of the sun's light during the eclipse. The field of view of this device was made sufficiently wide to take in a large area of the sky in order to minimize the effect of an individual cloud during cloudy weather. The front cover also shows the Gardner 18-foot camera installed for corona photographs. The rain prevented use of this camera and the 8-mm. receiver.

Each radio telescope consisted essentially of a sensitive receiver connected to an antenna with a beam that was sufficiently narrow to achieve high gain and yet wide enough to encompass the whole sun. Thus, when the axis of the beam was pointed at the sun's center the integrated radiation from the entire sun was presented to the receiver. The receiver for 65 centimeters was a conventional superheterodyne (with precautions taken to achieve a maximum of stabilization). The output of the second detector was fed to a recording milliammeter after passing through a direct-current amplifier. The receivers for the other three equipments were of the chopper type,[10] and here again the direct-current output from the receiver, which is proportional to the input radio-frequency power or intensity, is fed to a recording milliammeter. The chopper-type receivers were frequently calibrated by a standard signal from a self-contained black body kept at a known elevated temperature. Electric power was obtained from gasoline engine driven motor generators. Since all of the equipment required a very stable supply voltage, the generators were regulated for both frequency and voltage. In addition, voltage regulating transformers were used at each of the equipments. Time ticks were recorded by means of a second pen on each of the recording milliammeters. The rate of the chronometer was established by radio signals from WWVH, Maui, T. H.

The variation in the received signal at three, 10, and 65 centimeters is shown in the graph. The curves have been normalized between the readings obtained from the uneclipsed sun and when the radiometers were pointed at the sky several degrees from the sun.

Although these curves have not been reduced, it can be seen that the amount of the residual radiation at totality increases with wave length, as is expected from theoretical considerations. The effect of enhanced emission roughly associated with the immersion and emersion of the two main sunspot groups present during the eclipse, A and B, can be noted.

First, let us consider the curve for 65 centimeters. The bumps at first and fourth contacts are believed to be due to constructive interference between the direct ray from the sun and the ray reflected from the steel matting out in front of the antenna. The decrease in signal near 3:10 UT and the increase near 4:17 UT appear to be caused by enhanced emission associated with sunspot region A, which was near the center of the solar disk. Similar, though smaller effects are associated with sunspot region B, which was near the eastern limb of the sun. The sharp dip in the curve near 3:20 is partly spurious and is due to an antenna alignment error.

The 10-cm. curve was affected adversely by the rainstorm. The wind and rain are believed to have caused the decrease in signal around the time of first contact and the fluctuations after fourth contact. It is estimated from earlier measurements that the rain reduced the sun readings 15 to 30 per cent. It is also estimated that the enhanced emission over and above the quiescent radiation was less than 50 per cent of the quiet emission. This is a relatively low value for 10-cm. radiation, and is consistent with the small amount of solar activity noted on the day of the eclipse. The total spot area was about 400 mil-

The four radiometers on the day of the eclipse. The waveguide of the 8.5-mm. receiver (right) is shaped like a shepherd's crook. Part of the photocell apparatus may be seen projecting over the top of the ring.

lionths of the visible hemisphere, divided almost entirely in two groups.

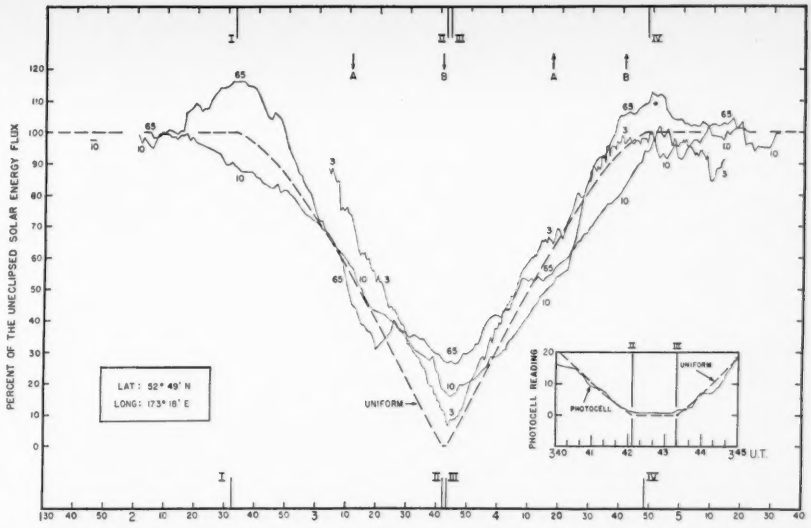
It is possible to distribute the amount of enhanced emission among the various regions of solar activity (as indicated by sunspots, plages, coronal green areas, and the like, which are suspected of emitting enhanced radiation) so as to obtain as close a fit as possible to the hypothetical eclipse curves for the quiet sun, after the effect of these enhanced sources is subtracted from the measured eclipse curve.

If we assume that the 10-cm. emission remaining after this correction is of thermal origin, then the analysis appears to favor the model based on temperatures below 30,000° K. in the lower chromosphere. It can also be concluded, if the area of the source of the enhanced radiation is the same as the associated sunspot area, that the intensity of the source is equivalent to that of a black-body radiator at about 40 million degrees K., which is of the same order as that obtained by Covington during the partial eclipse of November 23, 1946.[11]

It is estimated that the sun reading at three centimeters was reduced 35 to 50 per cent by the rain. The variability of the rain is believed to account for the high values during the first phase, around 4:10 and 4:30 UT, and the low value after fourth contact. Equipment failure was responsible for the loss of data before 3:05.

After corrections are made for the effect of the rain and the shape of antenna beam across the disk, background emission, the thermal radiation from the moon, and the enhanced emission (only about 6.5 per cent), the magnitude and shape of the corrected curve around totality agree quite well with the thermal emission hypothesis. The corrected curve falls between the two curves derived from limb brightening models, and therefore it does not favor either. Although little weight can be given these 3-cm. observations because of the rain and loss of data, it is believed that the effect of rain remained fairly constant during the five-minute period around totality, which is the sensitive zone for discriminating between various models. The sharp dip in the eclipse curve at totality occurs at the correct time and has the right form as that from the "bright ring" of radio emission expected on the quiet-sun theory of thermal emission. A uniform disk with a diameter four per cent larger than the visible disk of the sun would give the same residual value, but it would have a much broader minimum.

It has also been concluded that if the area of the radiating source of enhanced emission is the size of the spot, then the intensity is equivalent to a black-body radiator at about two million degrees Kelvin, which is lower than that for the 10-cm. data, as would seem reasonable.



Unreduced observed eclipse curves for 3, 10, and 65 centimeters and a curve (dashed) based on uniform visual brightness of the sun. The inset shows photocell readings for timing totality. The horizontal scale is Universal time, September 12, 1950. The four contact times and times of covering and uncovering sunspot groups A and B are marked.

These results thus give evidence in favor of a relatively cool lower chromosphere and some evidence in favor of limb brightening at three centimeters.

We wish to acknowledge the generous assistance of E. A. Beck, Harold Herman, C. H. Mayer, T. P. McCullough, R. J. McEwan, R. M. Sloanaker, C. B. Strang, and D. R. J. White, for constructing the equipment and taking the data, to David Hawkins for photographic work, and to Commander C. W. Harrison, Jr., for his contribution toward the planning and support of the expedition.

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TERMINOLOGY TALKS

J. Hugh Pruett

As we have seen, the day is a natural astronomical unit of time, based on definite positions of heavenly bodies or of imaginary points on the celestial sphere. The next unit used in our calendar is one to which no certain astronomical significance has ever been attached. In the University of Oregon correspondence study courses, prepared and administered by the present writer, one question in Lesson I reads: "Can you give any reason for the length of the week?" The answers to this over many years follow in general the pattern of ideas of various theological, historical, and scientific scholars.

The Week

Some students with deeply religious backgrounds believe the week is of divine origin and was arranged by the Creator "in the beginning" when He made heaven and earth. His six days of work with the seventh one of rest established the week, they say.

Others believe it came about through the observed changes of the moon. The so-called new moon, first quarter, full moon, and last quarter occur about seven days apart, the average being almost 7.4 days. Although the actual new moon is too near the sun and cannot be seen, it is easy to observe that from "half" moon to full moon is approximately a week, and from full moon to the next phase (last quarter) is about the same.

One author says, "The week is a unit of time made by man." This seems to be borne out by the fact that weeks vary in length with different peoples.

The term *week* is said to come from the Anglo-Saxon "wicu" and the Germanic "wikon," which seem to indicate a turn or a change. The Greeks evidently had no time division corresponding to the week, and the Romans not until long after the beginning of the Christian era. The seven-day week seemingly had its origin in western Asia in very ancient times, and later became

(Continued on page 121)

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 84th meeting of the American Astronomical Society at Haverford, Pa., in December. Complete abstracts will appear in the Astronomical Journal.

Lithium in the Sun

Estimates of the abundance ratio of calcium to lithium on the earth and in meteorites range between 6,000 and 600, whereas in the spectrum of the sun and sunspots Drs. Jesse L. Greenstein and Robert S. Richardson, of Mount Wilson and Palomar Observatories, find that the ratio is about 150,000. There is no doubt that lithium in the sun is less abundant compared to the other metals than it is on earth. This is not unexpected, because the depletion by a factor of about 100 can be ascribed to thermo-nuclear processes in the sun, which become important for lithium at a temperature of 3.5 million degrees. A temperature of 3.2 million degrees is encountered at a point halfway from the surface to the center, and 96 per cent of the solar mass is hotter than this.

Thus, the existence of any lithium at all in the sun is a major puzzle, for at the center the lifetime of a lithium atom is only 300 seconds. It will quickly combine with hydrogen nuclei to form heavier elements. At the halfway point, with the temperature 3.2 million degrees, the lithium lifetime is only 10^8 years, still very short, and it is believed that any mixing or circulation from the atmosphere to the deep interior must be very slow (with a period near 600 million years). If rapid mixing exists, it must not reach as deep as the halfway point.

Accretion of lithium from space or from the fission of heavy elements on the sun by cosmic rays could produce lithium in the solar atmosphere, but there are many uncertainties in each of these possibilities.

AK Herculis

Dr. Carl K. Seyfert and Ewell E. Mason, of Vanderbilt University, employed a photoelectric cell and amplifier attached to the 12-inch DeWitt reflector to measure the light variations of the eclipsing double star AK in the constellation Hercules. The light curve shows that the stars revolve in a period of 10 hours 14 minutes. During each cycle two eclipses occur; the light is diminished by 36 per cent at primary and 25 per cent at secondary minimum.

Analysis of the light curve indicates that the two stars are tidally distorted into ellipsoids, revolving nearly in contact with each other with a relative orbital speed of about 475,000 miles per hour. The distance between the centers of the stars is about 750,000 miles; they have masses of about 25 per cent and 15 per cent that of the sun.

The Inner Metagalaxy

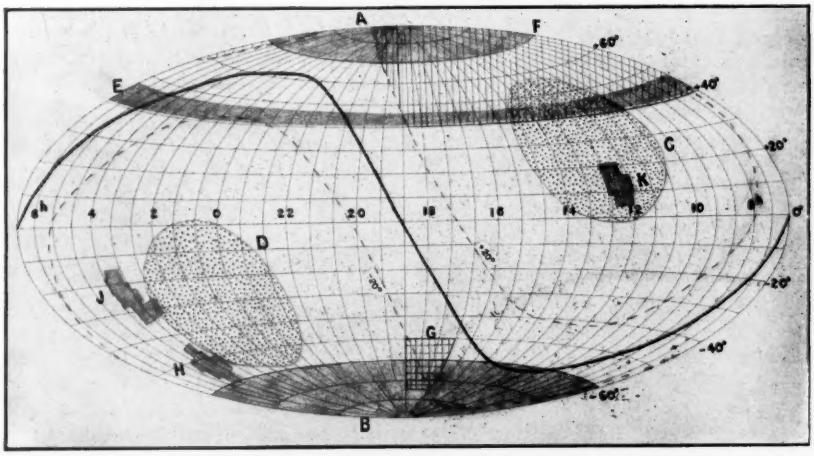
The distribution in space and other characteristics of the half million galaxies that are brighter than magnitude 17.5 was the subject matter of the 1950 Russell lecture, by Dr. Harlow Shapley, director of Harvard College Observatory. Eighteen years of observations at Harvard's Massachusetts and South African stations, with large-field cameras ranging in size up to the 16-inch Metcalf refractor and the now dismantled 24-inch Bruce refractor, have been analyzed. Some early plates made with patrol cameras in Cambridge and Peru have helped in cataloguing the thousand brightest galaxies, and the 60-inch reflector in South Africa has been used for some of the faintest.

Within 20 degrees on either side of the equator of the Milky Way, little can be learned about the distribution of external star systems because of the light-diminishing dust and gas of our own galaxy, but in more than half the sky the way is clear for a comprehensive survey that is without known limit in depth. It is estimated, from an incomplete analysis of the data, that one million new galaxies have been photographed on Harvard plates, with about one fourth of them identified and measured by Dr. Shapley and his assistants.

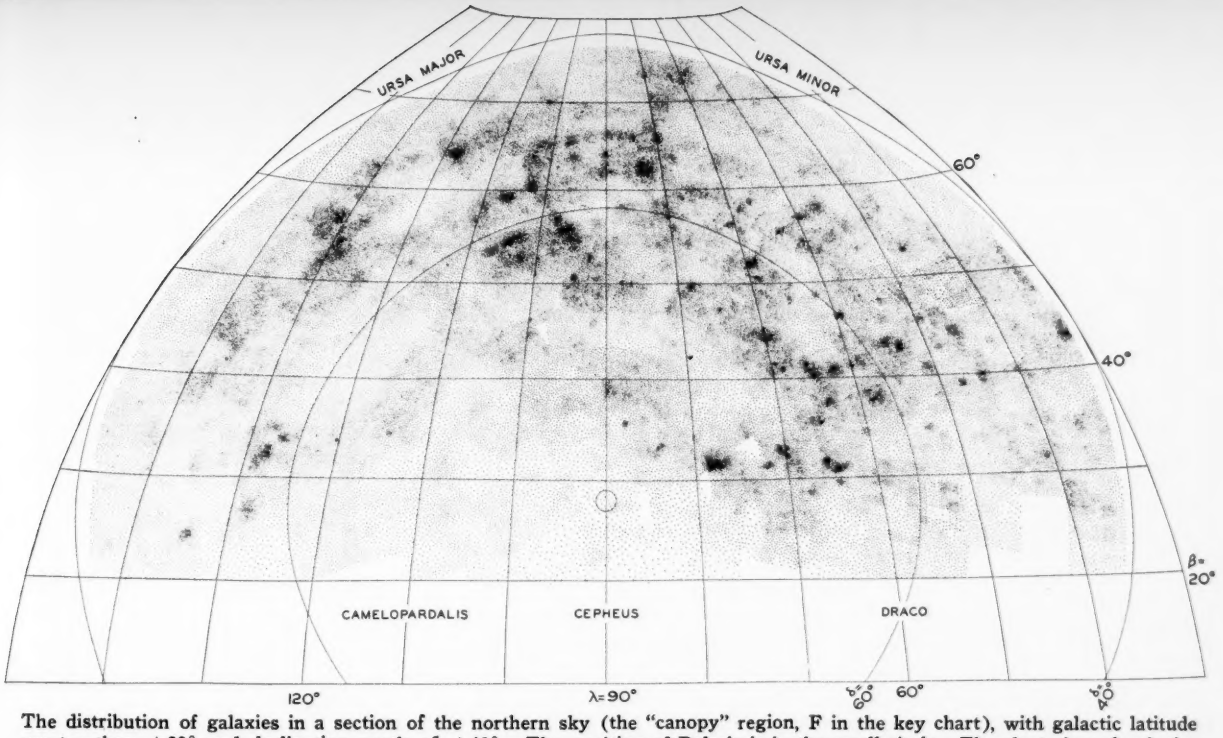
Apparent photographic magnitude 17.5 corresponds to a distance of roughly 80 million light-years for the average galaxy, and this distance represents a total volume of space of the order of 10^{24} cubic light-years. Giant galaxies similar to our own get into the survey, even if they are four or five times as distant as the average, whereas dwarf systems are imperfectly represented in the census because of their faintness.

In the dust-free half of the sky, where most of the work is done, the volume of space that on the average must be surveyed to find one galaxy like ours is about 10^{20} cubic light-years; the volume is 6×10^{18} cubic light-years for one average-sized galaxy. To the limit of magnitude 17.5 chosen for the survey of the inner metagalaxy, there are on the average 24 galaxies per square degree of sky (the moon covers one fifth of a square degree). From this number it may be calculated that for the dust-free regions there would be observed about 500,000 galaxies brighter than magnitude 17.5; probably an additional 150,000 may be observed nearer the plane of the Milky Way.

Assuming that the population is *on the average* uniform throughout the space in which galaxies can be photographed with the greatest instruments, there should be available a billion galaxies within a distance of a billion light-years. Concealed by the obscuring mat-



Regions of special Harvard surveys that have been completed to photographic magnitude 17.5 and fainter in the inner metagalaxy census are marked on an Aitoff projection of the entire sky (co-ordinates in right ascension and declination). A is the north polar cap, and B the larger south polar cap; C and D are the north and south galactic caps, 30 degrees in radius around each pole of the galaxy. E is a zone around the sky between declination +41° and +46°, to test the dependence of galaxy distribution on distance from the Milky Way. F is the "canopy" region of bright galaxies shown on the accompanying chart. G, H, J, and K are smaller areas where preliminary surveys to great distances were made, G being a "window" in the absorbing material along the southern Milky Way. The heavy curve represents the galactic equator; +20° and −20° mark the approximate boundaries of the Milky Way, inside of which few galaxies are photographed.



The distribution of galaxies in a section of the northern sky (the "canopy" region, F in the key chart), with galactic latitude greater than +20° and declination north of +40°. The position of Polaris is in the small circle. The clustering of galaxies is illustrated, and also their apparent scarcity in low galactic latitudes. Harvard Observatory chart.

ter in and alongside the Milky Way are a billion more galaxies that are impossible to record but predicted to exist.

As yet there is no evidence in the survey, or in deeper surveys, of a dominant center in the metagalaxy, or an edge to this galaxy of galaxies. The volume of a billion light-years radius, the approximate limit for observations with the 200-inch telescope, still appears to be a small fraction of the galaxy-populated universe, and probably not over one per cent of the galaxies are in that volume.

A study of the many groups of galaxies leads to a revision of an earlier estimate that three out of every four galaxies are of the spiral type. Now it appears that less than half of the galaxies are spiral in character. Thinly populated dwarf spheroidal galaxies and such irregular systems as the Magellanic Clouds are found, chiefly by the Mount Wilson and Palomar observers, to be relatively very numerous, at least in our immediate neighborhood.

Studies of the inner metagalaxy and especially of our own system have strengthened the hypothesis that the direction of the evolution or development of galaxies is not from the spheroidal type to the discoidal and spiral forms but in the opposite direction. Dr. Shapley believes that, as a result of the radiations and motions of their millions of component stars, galaxies develop from the chaotic irregular forms through the various grades of ever more compact spirals to the smoothly arranged ellipsoidal or spheroidal systems. The times required for evolutionary developments are of the order of billions of years; and since many spirals still exist, we may conclude that the universe is still in a youthful state, from the standpoint of galactic dynamics and radiant energy.

Dr. Shapley recently found that the Small Cloud of Magellan is essentially dust-free, whereas the Large Cloud is still rich in material for the birth of new low-density stars. Hundreds of these presumably young supergiant stars are seen in the Large Cloud, some of them 10,000 times as bright as our sun and so large that each would completely fill the orbit of Jupiter, a thousand times the diameter of the sun.

The Milky Way divides the sky into two halves. The metagalactic survey has long since shown that out to a distance of many million light-years the northern half is nearly twice as populous in galaxies as the southern half. Conspicuous differences in population from region to region are found, indicating large-scale non-uniformity in galaxy distribution. All through the Harvard census, they come in pairs, groups, clusters, and larger aggregations, much as the human population of the United States is unevenly distributed but averages 50 persons per square mile.

A new study of distribution in the north galactic cap, the richest part of the sky for galaxies, is being completed on 126 three-hour photographs, half of which were made in South Africa. More than 100,000 galaxies are found in the zone of 2,800 square degrees, which is labeled *C* on the accompanying chart, page 114.

Astroballistic Heat Transfer

The process of the transfer of heat from the atmosphere to a meteor plunging through it, which results in the loss of mass by the meteor, is being investigated by Drs. Richard N. Thomas and Fred L. Whipple, of the University of Utah and Harvard University, respectively. They have found that heat transfer in the region where the solid body just begins to melt varies directly as the air density, rather than with the square root of the density as is assumed in current aerodynamic theory.

About one per cent of the energy of a column of gas in the path of a moving body goes into heating it at low velocities (on the order of a mile per second), whereas at real meteor speeds about 10 per cent of the energy is transferred. The temperature of the meteor surface near its maximum light is about 2,800° absolute. Dr. Whipple is at present computing the largest size a single meteorite may have and survive without breaking apart during its fall all the way to the surface of the earth.

Polarization Around the Trapezium

An attempt by Dr. John S. Hall, U. S. Naval Observatory, to measure polarization in the light of the members of the Trapezium in the spring of 1949 revealed that the Orion nebula is polarized. A micrometer, later attached to the guiding telescope of the 40-inch Ritchey-Chrétien reflector, made it possible to explore this nebula in some detail. The area of the sky admitted to the cathode of the photomultiplier at any one time was 380 square seconds of arc.

Preliminary measures made on three nights show that the plane of polarization consistently points toward the Trapezium as the source of light. Since

(Continued on page 121)

NEWS NOTES

By Dorrit Hoffleit

FIFTY YEARS OF STELLAR SPECTROSCOPY

The half century just passed has seen no more significant progress in astronomy than can be attributed to the examination of stellar spectra. Prior to 1900, work in astronomical spectroscopy had been primarily experimental and exploratory. In the future, on the other hand, although great advances from the application of spectroscopy are expected, it does seem likely that the most outstanding achievements may be anticipated from the development and extensive application of electronic equipment to astronomical problems. Dr. Alfred H. Joy, of Mount Wilson Observatory, appropriately chose "Stellar Exploration with the Spectrograph" as the topic of his address as retiring president of Section D (Astronomy) of the American Association for the Advancement of Science at Cleveland on December 27th.

From the small-dispersion spectra used by Miss Cannon at Harvard to classify some quarter of a million stars, to the relatively very large dispersion with which Walter Adams at Mount Wilson showed that interstellar lines are sometimes multiple, indicating that interstellar absorbing matter is not uniformly distributed in the galaxy, a tremendous amount of knowledge about stars and the universe has accumulated that could never have been ascertained from direct photographs alone. These facts comprise stellar composition, temperature, pressure, luminosity; stellar and solar motions; the distances and distributions of stars and obscuring matter; the rotations or pulsations of certain classes of stars, and other topics. It was from spectroscopic data, particularly radial velocities, that the existence in the galaxy of Baade's two stellar populations was demonstrated as recently as 1944.

Problems of the abundances of elements and turbulent motions in star atmospheres require many future spectroscopic observations. And the magnetic fields in stars present a new challenge which Mount Wilson spectroscopists are avidly meeting at the turn of the half century.

MINOR PLANETS

How many asteroids are there and what is their total mass? In *Popular Astronomy* for November, 1950, C. H. Schuette, of Munich, Germany, tackles the problem anew. From the ranges in brightness of the first 500, he deduces that nearly all of them down to the 12th magnitude at opposition have already been found, most new ones now being about magnitude 14 at opposition.

He derives the distribution of the sizes of the asteroids from their mean distances, magnitudes, and an assumed albedo (reflecting power) of 0.24. He finds that practically all asteroids with radii greater than 50 kilometers have been discovered. On the assumption of a mean density for asteroidal material he computes the aggregate mass. The very small, undiscovered bodies, though obviously large in number, contribute very little to the total mass. On the other hand, the neglect of the five brightest asteroids would alter by about 10 per cent the total estimated mass of between 0.94 and 1.82 x 10^{-8} the mass of the sun.

Roughly, Schuette finds that among minor planets with radii up to 20 kilometers average or to visual magnitude 14 at least about 1,500 are still missing. But for two magnitudes fainter they number in the tens of thousands, and "their complete research, calculation, and observation with the methods of today will be nearly without any hope of success."

The problem of the asteroids is very complex, but Schuette's simplified solutions probably give very closely the correct order of magnitude of the various quantities he derives.

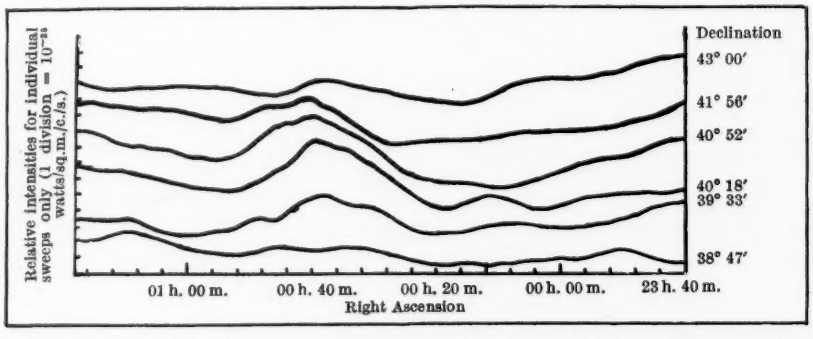
RADIO ENERGY FROM M31

At Jodrell Bank Experimental Station of the University of Manchester, England, R. Hanbury Brown and C. Hazard have completed the first successful detection of radio noise from an external galaxy, M31, the Andromeda nebula. They employed the world's largest antenna, a paraboloid built of wire mesh to have an aperture of 218 feet and a focal length of 126 feet. Although this apparatus is necessarily fixed in position, pointing to the zenith, the primary receiving unit can be swung back and forth at the focus to receive energy at least 15½ degrees on either side of the zenith.

According to the account in *Nature* (November 25, 1950), the experiment consisted of fixing the beam (two degrees wide) at a number of different elevations, so that in each 24-hour period it swept over a strip of sky two degrees wide. Six such strips centered between declinations 38° 47′ and 43° 00′ north indicated a conspicuous source of radiation at $0^h\ 40^m$, +40° 55′. The coordinates of the Andromeda nebula are $0^h\ 40^m$, +40° 59′.

At the frequency employed, 158.5 megacycles, the dimensions of the source of radio energy appear to be ¾° by ½°, of the proper size and orientation to be identified with M31; this size was checked with records of celestial radio "point" sources, in particular the bright radio star in Cygnus, which is known to have a diameter of less than six minutes of arc — small in comparison with the beam width.

From the intensity of the radiation, the effective black-body temperature is about 1,000° K., which compares with Reber's similar determination for the nucleus of our galaxy, 1,500° K.



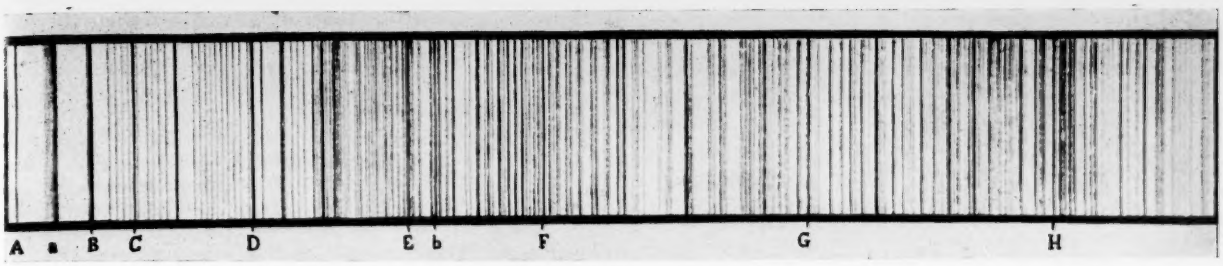
Coinciding humps in four of the six sweeps, plotted here with arbitrary vertical displacement, reveal the radio emission from M31. Reproduced from "Nature."

IN THE CURRENT JOURNALS

NOTES ON THE 1P21 PHOTOMULTIPLIER TUBE WHEN USED FOR ASTRONOMICAL PHOTOMETRY, by J. H. DeWitt, Jr., and C. K. Seyfert, **Publications** of the Astronomical Society of the Pacific, December, 1950. The equipment at Vanderbilt is described, and the chief sources of leakage currents and their remedies are outlined, together with a simple method for distinguishing between cell leakage current and dark current.

THE POLYNESIAN, MASTER MARINER AND ASTRONOMER, by G. S. Mann, **The Irish Astronomical Journal,** December, 1950. "At a time when the western mariner was largely confined to the Mediterranean, creeping cautiously along its seaboard, the Polynesian, confident in his own skill and courage, regularly covered thousands of miles of open sea, and was indeed the Master Mariner of all time."

THE ADVENT OF THE QUANTUM THEORY, by Albert Einstein, **Science,** January 26, 1951. "This interpretation, which is looked upon as essentially final by almost all contemporary physicists, appears to me as only a temporary way out." Also four other papers in the same magazine commemorate Max Planck and 50 years of the quantum theory.



Compare this copy of Fraunhofer's map of the solar spectrum with the Mount Wilson spectrum on the back cover.

The Fraunhofer Lines

By Otto Struve, *Berkeley Astronomical Department*
University of California

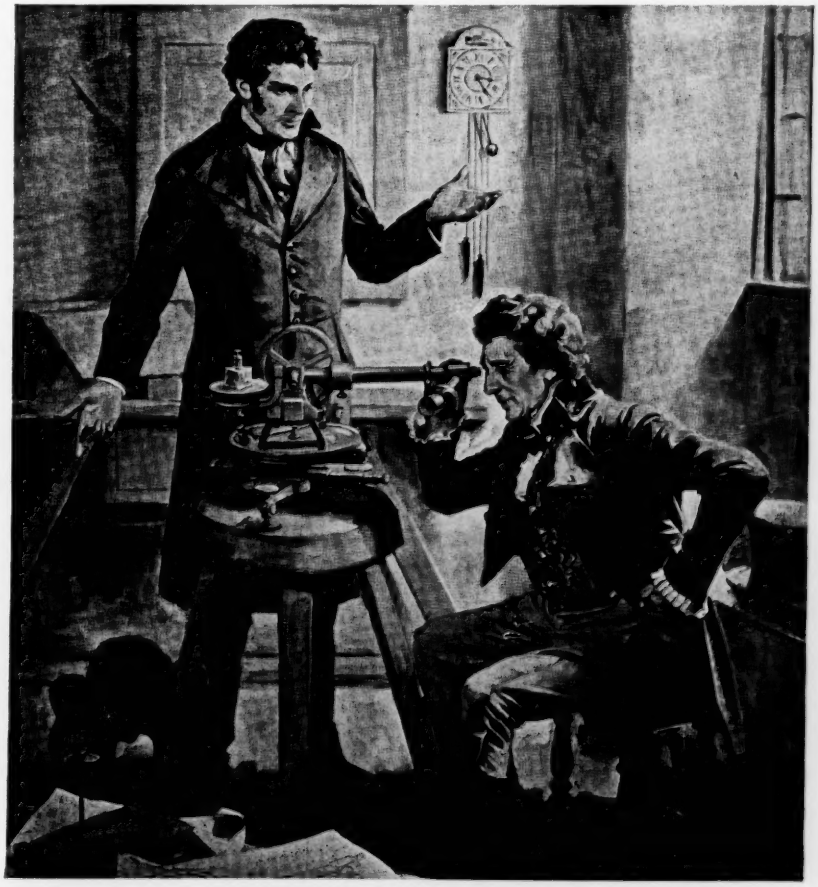
On July 21, 1801, a fire broke out in the optical establishment of a Munich looking-glass maker. The flimsy structure collapsed, burying under its ruins the workers and their tools. All were killed except a 14-year-old apprentice, Joseph Fraunhofer, who, though seriously injured, was rescued from the flames. It happened that the Bavarian ruler witnessed the scene, and took an interest in the boy, presenting him with the sum of 18 ducats, thus enabling him to purchase some books and a glass-finishing machine. Sixteen years later Fraunhofer published in the *Denkschriften der Königlichen Akademie der Wissenschaften zu München* one of the great classics of astronomy — his announcement of the discovery of what we now call the Fraunhofer lines in the spectrum of the sun.*

He had cut a long narrow slit in the window shade of a darkened room and permitted sunlight to pass into the room through this slit. At a distance of 24 feet he had placed a small theodolite with a 60° prism in front of it. When the narrow beam of sunlight was allowed to pass through the prism and when the telescope was focused at the slit, he saw "an almost countless number of strong and weak vertical lines, which are, however, darker than the rest of the color-image; some appeared to be almost perfectly black . . . . If the opening through which the light entered was made broader, the fine lines ceased to be clearly seen . . . . The relations of these lines and streaks among themselves appeared to be the same with every refracting substance [in the prism]; so that, for instance, one particular band is found in every case only in the blue; another is found only in the red; and one can, therefore, at once recognize which line he is observing . . . .

"I have convinced myself by making experiments and by varying the methods that these lines and bands are due to the nature of sunlight, and do not arise from diffraction, illusion, etc. If light from a lamp is allowed to pass through the same narrow opening in the window-shutter, none of these lines are observed, only the [double] bright line *R*, which however, comes exactly in the same place as the [double black] line *D* [in the spectrum of sunlight]."

Later Fraunhofer found that the moon and the planets had dark-line spectra which were in general identical with that of the sun. This also held for some of the fixed stars, for instance, Pollux and Capella. But other stars, notably Sirius, showed "with certainty . . . three broad bands which appear to have no connection with those of sunlight; one of these bands is in the green, two are in the blue."

Thus a new branch of astronomical science was created, and it is thriving to this day. In 1861 Kirchhoff repeated Fraunhofer's observation of the coincidence of the dark *D* lines in the sun with a double bright line in the light of a flame — an experiment which had been amplified in the meantime by Foucault — and enunciated his famous law which became the foundation for all later investigations of stellar spectra. It enabled astronomers to search for the proper identification of the Fraunhofer lines



A painting of Fraunhofer demonstrating his analysis of the solar spectrum.

*A translation of a part of Fraunhofer's original paper may be found in Shapley and Howarth: *A Source Book in Astronomy*, McGraw-Hill Book Company, New York, 1929. A few dark streaks in the sun's continuous spectrum were noticed by Wollaston in 1802.

with spectral lines produced in the laboratory by different chemical substances. It is this problem of measuring and identifying the Fraunhofer lines that we shall discuss this month.

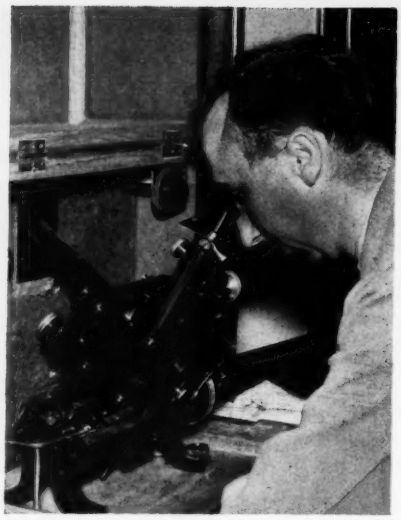
Fraunhofer measured 754 absorption lines in the solar spectrum. The 1928 revision by St. John and others at Mount Wilson of the great table by Rowland of the sun's Fraunhofer lines contained approximately 22,000 lines. Since then thousands of new lines in the near infrared have been measured at Mount Wilson; the extreme ultraviolet spectral region is being explored at Johns Hopkins and at other institutions connected with the White Sands rocket station, for this region can only be observed at altitudes within our atmosphere where the ozone absorption is not prohibitive; and in the extreme infrared or heat region, observations have been made with radiometers of different types, or with lead-sulfide photoconductive cells, at the University of Michigan and at Liége University.

There has been a remarkable expansion of our knowledge of the line spectra of stars, nebulae, interstellar gases, planets, comets, the solar corona, the night sky, the normal terrestrial atmosphere, and so forth. I have never seen an estimate of the total number of different Fraunhofer lines that have been recorded in the astronomical literature. It must be of the order of 100,000!

This vast mass of information is steadily growing and becoming more and more unwieldy. Even now it is beyond the scope of the average astronomer to keep up with progress made in this field, and the question is being asked from time to time: Is it really necessary to continue measuring more and more Fraunhofer lines, with higher and higher accuracy, and then to spend countless numbers of hours trying to identify the astronomical lines with lines measured in laboratory sources?

I vividly recall a past-midnight discussion which I had, many years ago, in the great dome of the Yerkes Observatory with the late Professor B. P. Gerasimovich†, who was then on a visit to the United States from Soviet Russia. I had been engaged in the measurement of radial velocities of *B*- and *A*-type

†The tragic fate of this distinguished astronomer and director of the Poulkovo Observatory, who disappeared in 1937, after one of the purge trials in the U.S.S.R., forms one of the saddest and most mysterious chapters of recent astronomical history. Many facts of his case have gradually become known, but some of the links are still missing. Because of the relentless policy of suppression of all knowledge concerning victims of the purges there has never been an appraisal of Gerasimovich's work, or an outline of his life, much less has there been a description of his trial. His name does not appear in the history of the Poulkovo Observatory (1839-1939), which was published in 1945 by the Academy of Sciences of the U.S.S.R.; and for a decade, or longer, there were no references to him, by name, in the Russian scientific literature.



Dr. P. Swings, University of Liege, measuring the lines in a spectrogram.

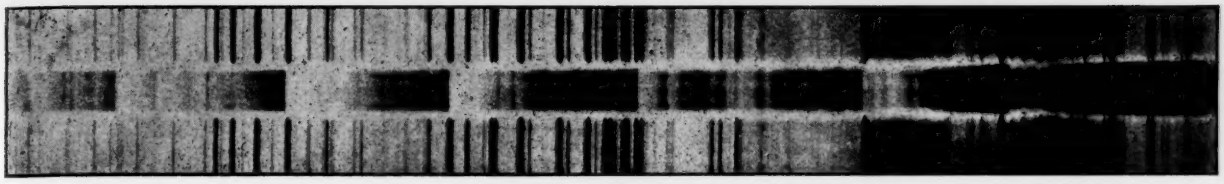
stars, and had been impressed with the fact that there were hundreds of absorption lines that had not before been measured or identified. In fact, the last comprehensive work on the Fraunhofer lines of the *B* stars was that of F. E. Baxandall, carried out in the early years of this century under Sir Joseph Lockyer's direction. This work was based upon objective-prism spectrograms of excellent quality. But even a crude inspection revealed vast numbers of lines which had not been seen by Baxandall. Should I embark upon a long program of measuring and identifying all absorption lines that I could see on the best Yerkes spectrograms? The prospect was not an attractive one. It would require months, or even years, of work, and the results would perhaps be disappointing. After all, we already knew that the composition of the stellar atmospheres resembles that of the sun, and that the differences in the intensities of the Fraunhofer lines were predictable in terms of the theory of ionization and excitation. What could we gain from finding more and more lines of ionized oxygen, nitrogen, and the like, when we already knew that these spectra were represented, and that the fainter laboratory lines were sure to become visible if the performance of the spectrograph were sufficiently improved? We talked all the rest of the night, and the upshot of it was that I got started upon my lifework — the detailed study of the spectra of early-type stars!

Almost immediately I noticed a faint line in the immediate vicinity of the strong helium line at wave length 4472. The new line was about two angstroms to the violet, and was strangely diffuse, even in stars having sharp lines of all the heavier elements. In fact, 4470 in its diffuseness resembled the ordinary well-known helium lines. But the ordinary laboratory spectrum of helium has no line at 4470. Next, I noticed that in some stars the new line was strong, while in others it was absent, and, strangely, this was not due to a difference of spectral type, or temperature. All stars in which the line was strong were normal main-sequence objects; all those in which it was absent were supergiants. The presence of this line depended upon the luminosity of the star, and thus was probably related to the pressure in the reversing layer. I began to suspect that this line was produced by the helium atom in a manner that does not normally occur in the laboratory. In fact, I searched through the physical literature, and found that T. R. Merton had measured it in a discharge tube of helium when the pressure of the gas was large, while J. Stark had found it when a strong electrical field was applied to the glowing gas.

But a strange coincidence prevented me for some time from clinching the identification of 4470 with a forbidden transition in the helium spectrum (so called because under ordinary conditions in the laboratory the line is not visible; it is "forbidden" by the laws of the Bohr atom). Not far from the strong permitted helium line at wave length 4472 the *B*-type stars contain a strong line of ionized magnesium at 4481. About two angstrom units to the violet, at 4479, there was another, previously unknown absorption line. It looked strikingly like some sort of a ghost, or reflection of the magnesium line; and this in turn made me wonder whether 4470 was physically real. Perhaps it, too, was a ghost of He 4472?

But further study soon convinced me that 4479 was not related to the magnesium line. It was, in fact, a line of the doubly ionized atom of aluminum, not previously known to occur in stellar spectra. My instrument was free of ghosts and the line at 4470 was also real. Thus was found the first forbidden absorption line of helium, and it was the first to prove that the Stark effect produced by the charged particles in the ionized atmosphere of a star is an important astrophysical phenomenon. All of these results were unexpected and were the direct consequence of the systematic and, by itself, very monotonous analysis of all Fraunhofer lines in *B* stars upon which I had embarked.

It is easy to give other examples that prove the value of detailed study of the Fraunhofer lines. The accurate measurement of a single sharp line in the hotter stars at 4300.3 angstroms, at the Mount Wilson Observatory, led to the discovery of interstellar molecules. And P. Swings' identification of an emission line at λ5806 in Wolf-Rayet stars of the nitrogen sequence as originating in trebly ionized carbon led to a revision in the classification of these objects. One group was thought to have nitrogen and no carbon; the other, carbon and no nitrogen. However, while this distinction is



A spectrum of the red variable star Mira (Omicron Ceti) that shows the complexity of the molecular bands (mostly titanium oxide) in a cool star, and both atomic absorption and emission lines.

still recognized, it is not as sharp and mutually exclusive as we once thought.

Because of the rapid multiplication of the results obtained from the study of the Fraunhofer lines, and also because of the importance of work upon the spectra of atoms and molecules in the laboratory, the International Astronomical Union, in co-operation with the International Union of Pure and Applied Physics, has set up a special committee under the International Council of Scientific Unions. The astronomical members of this "Joint Committee on Spectroscopy" are Edlén, Gatterer, Herzberg, Swings, and Mrs. Moore-Sitterly. There are an equal number of delegates from the Physics Union. Last September this group held a meeting in London in order to discuss the outstanding problems and arrange for their solution. Of special importance was a lecture by Professor Swings, of the Astrophysical Institute of the University of Liége, Belgium, on the "Spectroscopic Problems of Astronomical Interest."

Professor Swings combines in a remarkable manner the qualifications of an experimental and theoretical physicist with those of an astrophysicist. He spent some years of his versatile career in physical laboratories, with Pienkovsky in Warsaw, and Edlén in Uppsala; and he built his own spectroscopic laboratory in Belgium, where his associates, Migeotte, Rosen, and others, are engaged in the study of those atoms and molecules that are not yet sufficiently known to provide the necessary astrophysical identifications. He also has had more than the average astronomer's experience with large telescopes and astronomical spectrographs — at Paris, Yerkes, McDonald, and Mount Wilson.

Thus, when Swings realized that in the hotter stars many Fraunhofer lines remained unidentified despite the most careful search among the spectra of laboratory sources, he joined Edlén in Sweden, and before long we had at our disposal not only a complete analysis of the laboratory spectrum of doubly ionized iron, but also its identification in the stars and nebulae, including those numerous computations of forbidden transitions which were never observed in the laboratory, but which could be accurately predicted once the permitted spectrum had been analyzed. Unquestionably, Dr. Swings possesses today the greatest accumulation of experience and knowledge in the study of the Fraunhofer lines. His report is to be published in full, but a few of the highlights of his London presentation are given here.

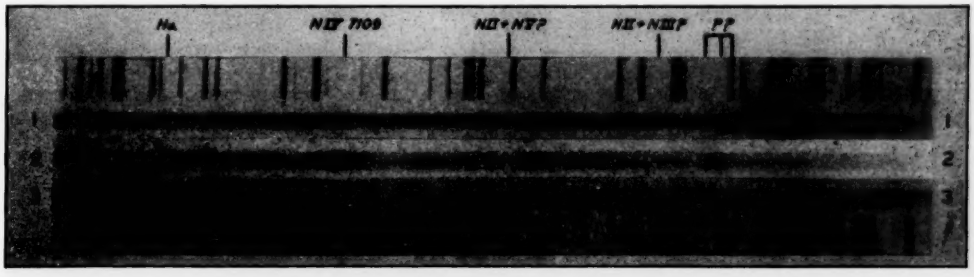
The greater part of the report dealt with "Unidentified Lines or Bands in Astronomical Spectra." This was followed by a shorter section entitled, "Descriptions, Classifications and Other Spectroscopic Data which are Desirable for Astronomical Applications." In reading the first part one is impressed by the enormous number of lines which are still unidentified. In the second part the most revealing sentence is the last: "This report provides me with an opportunity of thanking the faithful spectroscopists who in recent years have endeavored to provide the astrophysicists with the necessary spectroscopic data." The author could have inserted the word "few" before "faithful"! Understandable though it may be that most physicists have turned away from spectroscopy, the fact remains that only a very few continue to work along those lines which are of special interest to us. Astronomers recognize this situation, and there is a tendency among the younger astrophysicists to follow Swings in combining the work of the laboratory spectroscopist with that of the telescopic observer.

To start with the spectrum of the sun, "it is now possible to add a great many new atomic and molecular identifications to the 1928 edition of the *Revised Rowland Table of Wave Lengths.*" But even so, "there still remain thousands of unidentified absorption lines." In the ultraviolet region about 25 per cent of the measured lines remain unidentified. In the near infrared, "there remain approximately 1,300 unidentified solar lines. In the more distant infrared, accessible only with special instruments, several hundred solar lines have been identified," mostly on the basis of predicted wave lengths computed from the known levels. In this extremely important spectral region, laboratory studies of even the more common atoms and molecules are almost completely missing.

The spectra of sunspots, though fairly well investigated, contain numerous unidentified atomic lines measured by Mrs. Moore-Sitterly. There is also a well-marked molecular band near 6050 angstroms, measured by H. D. Babcock, which is unidentified.

The spectrum of the corona, once the greatest mystery of solar physics, has finally yielded to the concerted efforts of many spectroscopists. The principal lines were all identified by Edlén, in 1942, with highly ionized atoms of iron, calcium, nickel, and so forth. Only six coronal lines remain unknown, and two are doubtful.

As we pass toward the cooler stars, we observe an enormous number of new molecular bands and a dense network of faint and strong atomic lines, so heavily blended that progress is slow and laborious. The more conspicuous features in the standard stars have been measured, especially by Miss D. Davis, but many remain unidentified. Swings points out that the reason is partly lack of information about the laboratory spectra of some very common compounds such as titanium oxide, zirconium oxide, and so on, and partly the difficulty of resolving and separating related stellar bands or groups of lines from the great mass of unrelated absorptions. This difficulty can be met, at least to some extent, by careful comparisons of the spectra of many different stars. For example, P. C. Keenan, J. J. Nassau, and G. B. Van Albada have



The infrared spectra of three Wolf-Rayet stars that are rich in nitrogen lines: 1. HD 193077; 2. HD 192163; 3. HD 151932. Strong lines between about 8210 and 8260 angstroms are unidentified. McDonald Observatory photograph.

succeeded in isolating relatively strong bands of unknown origin in the latest *M* stars. Unquestionably, this is a particularly fruitful field for investigation at the present time.

Among the spectra of earlier types, there are many which require further study. In Procyon, of class *F*4, "8 per cent of the lines are unidentified, some of them quite strong." In the *A* stars, the situation is even worse. Thus, in the peculiar spectrum of Alpha Canum Venaticorum, "of the 3,017 lines measured between λ 3088 and λ 4741, 231 remain wholly unidentified, and numerous others are not completely explained." This spectrum and several others resembling it contain many lines of singly and doubly ionized rare earths, some in very great strength, but "the main difficulty arises from the fact that so little is known of doubly ionized rare earths in the laboratory, except of Ce III." The strange fact that the *rare* earths are so unexpectedly strong in these stars is probably connected with their magnetic properties (discovered by H. W. Babcock).

In the spectra of the *B* stars there are also many unidentified lines, probably all of atomic origin. Swings suggests that they may be caused by the doubly ionized metals, such as Ti III, Cr III, and the like, which are still unknown. Only Fe III has been studied in the laboratory.

The measurements by Swings and Jose of stellar emission lines in the infrared region of the Wolf-Rayet stars, from Hα to wave length 8800, were stymied "on account of absence of laboratory data." Even the strongest lines remain unexplained, or only tentatively identified by means of computed transitions between known energy levels which, however, have never been observed in the laboratory.

The peculiar emission-line stars, such as BF Cygni and Z Andromedae, have been very valuable in giving us observational data concerning the most important forbidden lines. For example, in the case of iron, the stars have given reliable measurements of those forbidden transitions that are produced by atoms having lost one, two, four, five, six, nine, 10, 12, 13, 14, and probably three, electrons. This leaves only the forbidden lines of neutral iron to be found, a task which Swings says will not be easy. None of these forbidden lines has ever been produced in the laboratory.

CORRECTION

I am indebted to Dr. W. Baade and Dr. R. Minkowski for informing me that they did not use interference filters in their early work on the Orion nebula, as was stated in the January issue of **Sky and Telescope**, page 58. The error arose through my having misunderstood a statement in J. G. Baker's article in Harvard Observatory **Monograph** No. 7, page 41, 1948.—O.S.

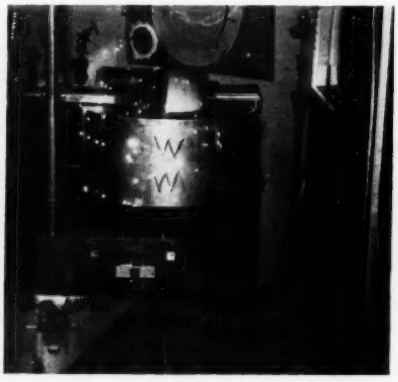
A Novel Home Planetarium

By Herbert Robinson, *Detroit Astronomical Society*

SEVERAL YEARS ago, I became interested in astronomy, particularly in the statistics of the stars and planets. But I would look up at the sky in the evening and all I could make out at first was the Big Dipper. In the summer the mosquitoes annoyed me and in the winter the cold weather bothered me, as I am no longer a young man. So I decided to buy or make something to help me learn faster.

I knew no one interested in astronomy, nor at that time did I know anything about the astronomical societies in Detroit, although I lived there at the time.

First, I bought a planisphere, but it did not seem to be of much use at night, and the stars shown below the equator formed distorted patterns. Next I obtained a 9-inch celestial globe, and I



The plastic cover on the projection globe is translucent only toward the parabolic reflector at the right.

tried looking at it in a mirror, because the stars are printed on the globe in reverse. But the flat mirror was not satisfactory either, as the globe did not show clearly except in the very center part nearest the mirror. I thought then that if I could get a concave mirror it might solve my problem.

A friend of mine who knew that I was interested in this happened to see some large war surplus mirrors for sale, and he phoned me about it. (By the way, he is now an ardent amateur astronomer also, has joined the Detroit group and is working on a telescope of his own.) Although these were large searchlight reflectors, 60 inches in diameter, I bought one of them. It is parabolic, about half an inch thick, and it taxed my ingenuity to mount it, as it is too heavy for one person to handle alone.

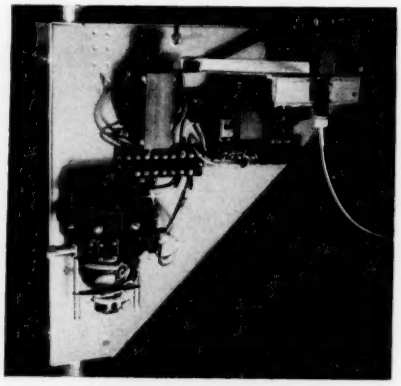
The mirror is now mounted with rubber strips supporting the glass wherever necessary, and is completely enclosed around the front and sides with plywood painted black and trimmed with aluminum angle strips.

I set the globe on a platform in front of the mirror, and rotated the globe in the frame that came with it. This arrangement was a big improvement over the flat mirror, except for the reflection of light from the lacquered finish on the globe. Therefore, I decided to put a light inside the globe to project the stars, and drilled nearly 400 holes of various sizes down to the 4th magnitude. I have a small workshop in my basement, which came in handy for all these operations.

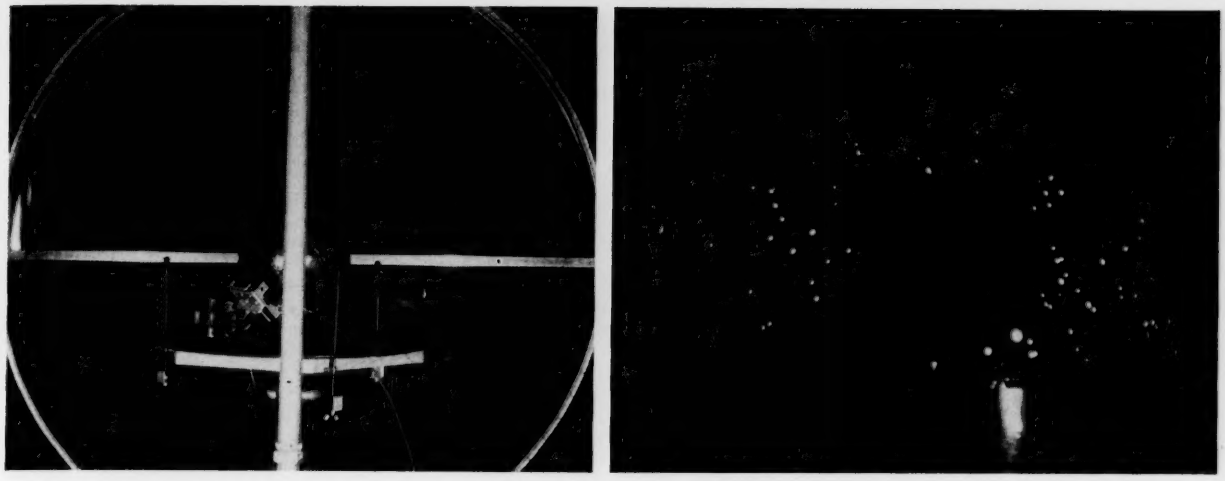
A jig was made so that all the holes would be drilled toward the center of the globe. From a list of stars in order of magnitude by constellation, I checked the globe carefully to see that each star was in the right location and of the proper brightness. The smallest drill required was .035 diameter.

The globe is mounted on a polar axis, as is any projection planetarium, and it turns by motor to reproduce the apparent motion of the sky. A transformer is used to supply the proper voltage for the light source, which is a small flashlight bulb. The globe itself was covered with white paper, which made the stars show better in the mirror but eliminated having them shine on the ceiling and walls of the room. Later, as the picture shows, the paper was replaced with a hemisphere of white translucent plastic, about 3/8 inch larger in diameter than the globe. The side of this hemisphere away from the mirror, toward the observer, is painted flat black.

This apparatus produces a very good illusion of the sky at night. The farther away I sit the bigger the reflection of the stars. The best distance is seven or eight feet back of the globe, with one's eyes level with the center of the globe and the mirror. The globe itself is too small to bother the observer, nor is the vertical pipe supporting the apparatus



The electrical and mechanical controls of the Robinson home planetarium.



With the room and mirror lights on, the Robinson planetarium and parabolic reflector appear as at the left. At the right, the sky of middle latitudes looking north is reproduced. The bright horizon reflection is from Capella, rising.

noticed at "night." When it is not in use, the plastic hemisphere slides up this pipe.

If all the front half of the globe toward the mirror is uncovered, and the horizon shield that shuts off the lower half of the mirror is removed, then the reflection from the mirror appears as if the observer were lying on his back on the ground, looking up at all of the sky in all directions. But this is not the usual way of viewing the sky, so that arrangement of the apparatus is not generally used.

The globe is placed central to and at the focus of the mirror, and it can be easily adjusted for any latitude from 90° north to 77° south of the equator. The focus is about 29 inches, and at the favorable distance for viewing, seven or eight feet from the globe, the sky shown in the mirror appears to be about 6½ times the original size. The stars are not compact, as the photograph might suggest, but spread out evenly to the observer.

I seat a visitor in the *comfortable* observing chair and he gets the illusion of being outdoors at night. No other light than from the stars is showing, except a small pinpoint flashlight with which I point out the stars as I stand beside the mirror and explain them. Although I made the apparatus to teach myself, it has developed into something to show to others, but not too many at any one time, as off to the side there is some distortion.

The black mark "W" in one of the pictures is for west. When that section is turned toward the observer, the western part of the sky is being shown in the mirror. The platform containing the globe turns in a complete circle, so that any direction of the horizon can be shown without the observer moving from the chair.

There are lights around the mirror, which are normally turned on, but controlled by a rheostat connected with another rheostat to the light inside of the globe. As the mirror lights are dimmed, the light inside the globe comes on, giving the impression of the night getting darker and the stars coming out.

The rheostat that controls the motor for turning the globe gives a variation of speed from about six minutes for one day's rotation to barely moving.

For my own observing, I purchased a Skyscope, but replaced its tripod with a folding one of aluminum tubing with folding aluminum cross braces. Worms and worm gears to turn the instrument in both right ascension and declination, circles with graduations for latitude and declination, sidereal hour angle, months, dates, and the like have been added. A compass and a level and detachable sights for locating the pole of the sky all are part of an outfit that weighs only 16 pounds and can be set up in a very few minutes without tools.

TERMINOLOGY TALKS

(Continued from page 113)

established in European countries.

Travelers in Africa have found various weeks, most commonly of three, four, five, six, and eight days, and nearly always associated with the interval between regular market days. The same tendency is found in several localities of South America and Malaysia. Among agricultural groups, one day of each week is often designated as a rest day, with no work permitted other than tending stock or visiting the market.

A writer in an old encyclopedia thought the ancient Egyptian seven-day week started on Saturday, and the Hebrews when leaving that country made Sunday the first day in order to differ from their long-time oppressors.

Also suggested as the origin of the seven-day week was the fondness of the ancient Babylonians for the magical number seven. This may have come about from the seven planets, or wanderers in the sky, that were known in those times. In addition to our five naked-eye planets, these included also the sun and moon. We readily recognize the planetary origin of the names of some of our present days of the week, such as Saturday, Sunday, and Monday. In the Latin of certain legal papers, the days of the week are Dies Solis, Dies Lunae, Dies Martis, Dies Mercurii, Dies Jovis, Dies Veneris, and Dies Saturni. Our English names, after some rearrangement and tongue-twisting, come from the Teutonic divinities.

AMERICAN ASTRONOMERS REPORT

(Continued from page 115)

the Trapezium stars show little or no polarization, it seems probable that the polarization of the reflected or scattered light is not substantially modified as it comes through the nearer regions of the nebula.

Dr. Hall is continuing these observations, and an attempt will be made to make them in different spectral regions. In his paper he also reported on photoelectric measures of polarization of 23 stars in the Pleiades.

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BOOKS AND THE SKY

FROM ATOMS TO STARS

Martin Davidson. The Macmillan Company, New York, 1950. 188 pages. $2.70.

THIS EXCELLENT little book on general astronomy first appeared in England in 1944, and a second edition was published in 1946. Its appearance in bookstores in this country is most welcome.

The arrangement of the material is as effective as it is unusual. A two-page introduction devoted to the solar system leads directly to the first chapter, entitled "Structure of the Atom." Following this, the author takes up the sun, earth, moon, planets, comets, meteors, zodiacal light, various aspects of stellar astronomy and astrophysics, and, finally, the origin of the planetary system. There are 13 appendices for the benefit of those readers who can follow a little more mathematics and physics than is contained in the main part of the book.

The first chapter is as good a brief, elementary account of atomic structure as one can find anywhere. However, neither this chapter nor the appendix dealing with the spectroscope has anything to say about the origin or production of spectra. There are no photographs of spectra, and nothing is said about the spectroscopic determination of chemical abundances in the sun and stars, although there is some mention of the composition of planetary atmospheres. The Harvard spectral classes are described in a page, and are used in two diagrams. Spectrum analysis has been such a powerful tool in astronomy that it deserves more attention in a book of this type.

The discussion of the planets is given in two chapters, one devoted to general considerations and the other to special details. This permits a discussion of periods, distances, masses, temperatures, and so forth, from a general point of view before the specific data for each planet are given. Three pages of tables end this section. One is necessarily impressed with the amount of information about the planets that has been acquired in the past five years, and these changes can be made in a new edition.

One of the best parts of the book is the discussion of the tides in the chapter on the moon. The exposition is clear, and numerical calculations are given to illustrate the points that are made. Also noteworthy, in the same chapter, is the summary of Professor Boring's work on the apparent size of the moon near the horizon, ending with a statement that the usual explanations "are extremely unsatisfactory and should be excised from astronomical textbooks."

The chapter on stellar radiation is an exceptionally fine piece of exposition, starting with the work of Lane and ending with the white dwarfs. The dilemma originally presented by the mass-luminosity relation is effectively discussed, as is its solution. The use of Einstein's theory to confirm the density of the white dwarfs is the reverse of the usual way of thinking about this, but is perfectly logical.

In discussing the source of stellar radiation, Dr. Davidson likens the stars to a millionaire who is living on his capital alone, except that the stars "carry out the policy of economy without conscious effort."

This book will be especially valuable for the amateur, or for the elementary student, who wants more information on some topics than is supplied in the standard textbooks but who is not ready to go on to more advanced books. It could serve as additional reading in most elementary college courses.

FRANK K. EDMONDSON
Goethe Link Observatory

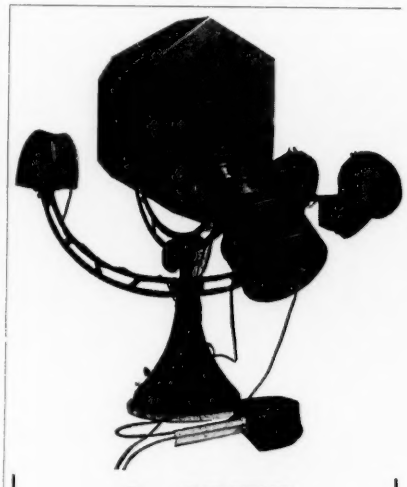
THE PHILOSOPHY OF MATHEMATICS

Edward A. Maziarz. Philosophical Library, New York, 1950. 286 pages. $4.00.

WITHIN THE COVERS of this one volume are to be found three distinct works: a work of scholarship, a historical survey, and a philosophical theory; and each of these deserves an independent evaluation.

For the first, Dr. Maziarz has offered us, in this publication of a doctoral dissertation, an excellent bibliography as well as a remarkably extensive set of notes that can be of real service to a scholar working in this field.

Secondly, the author attempts to give, in Part I, the history of the philosophy of mathematics. For the most part, how-



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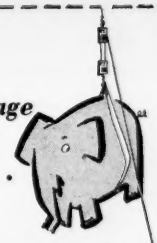
ever, this is identical with the general history of philosophy. The author undertakes, in a chapter entitled "Ancient Conceptions," a treatment of the Pythagoreans, with sidelights on Thales, Anaximander, Anaximenes, Heraclitus, Parmenides, Zeno and the Atomists, in three pages, Plato in three, and Aristotle in six. Similar limitations apply to the chapters on "The Cartesian Era," "British Empiricism," "Idealism and Positivism," and "Contemporary Directions." Given the limitations, the treatment is satisfactory, but it is necessarily inferior, even from the restricted point of view of the philosophy of mathematics, to what can be found in any good history of philosophy. It is thus suited only to the elementary student, and for him is rendered less desirable by the presence of numerous unenlightening notes and the author's choice of unnecessarily recondite words.

The author presents his own views on the philosophy of mathematics in Part II, and also in his introduction. Here the work descends to the level of special pleading, in which the philosophy of Thomas Aquinas is uncritically accepted. There is room for a discussion of this kind, but your reviewer objects to its presentation as though it were a critical comment on the contemporary philosophy of mathematics, to the frequent assertion of questionable theories as though they were not hypotheses to be defended but facts about which there was complete agreement, and to a definition of science which no scientist and very few philosophers would recognize, and a somewhat similar definition of other important terms. In short, the work could find a receptive audience, if at all, only from within the ranks of the New Scholastics. Those opposed will reject it of course, and those maintaining an open mind will find in it nothing to aid them in reaching a decision.

L. J. LAFLEUR
Florida State University



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NEW BOOKS RECEIVED

A GUIDE TO THE SKY, *Ernest Agar Beet*, third edition, 1950, *Cambridge University Press*. 95 pages. $1.75.

Written primarily for young people, this book will appeal to any beginner who wants to make some simple observations, as well as to read about the sky. An ecliptic map, and northern and southern star charts with a simple planisphere arrangement, are included.

PHYSICS OF THE SUN AND STARS, *W. H. McCrea*, 1950, *Hutchinson's*. 192 pages. 7s 6d.

A discussion of our present knowledge of the physical state of the universe, and a survey of the associated observational data and physical reasoning.

THE COMPUTATION OF ELEMENTS OF ECLIPSING BINARY SYSTEMS, *Zdenek Kopal*, 1950, *Harvard Observatory*. 181 pages. $4.00 paper; $5.00 cloth.

In this book, which is Harvard Observatory Monograph No. 8, the author discusses observational data and their treatment, computation of the intermediary elements, differential corrections, effects of orbital eccentricity, and computation of the elements of distorted eclipsing systems. Appendices deal with the solution of least-squares systems and computation of the errors, and a survey of the methods. The monograph is for the practical computer, and supplements Dr. Kopal's earlier work, "An Introduction to the Study of Eclipsing Variables."

DER STERNENHIMMEL, 1951, *Robert A. Naef*, 1950, *H. R. Sauerlander & Co.*, Aarau, Switzerland. 110 pages. SFr. 6.80.

The 11th annual publication of a handbook for observers sponsored by the Swiss Astronomical Society, containing day-by-day ephemeris material, a moon map, positions of the sun, moon, bright planets, asteroids, and interesting stellar objects. The annual is in German.

ASTRONOMISCHER JAHRESBERICHT, 1950, Astronomische Rechen-Institut, Seminarienhaus, Augustinerstrasse 15, Heidelberg, Germany. 364 pages. No price given.

This is the 48th volume of the *Jahresbericht*, covering literature of the year 1948. Astronomical articles in 108 magazines and publications from about 150 observatories and other institutions are classified and many are briefly abstracted in German under 14 major headings — general; activities, history; instruments and observing techniques; spherical astronomy, chronology; theoretical astronomy; theoretical astrophysics; sun; planets and moon; comets, meteors and meteorites, zodiacal light; stars; double stars; variable stars and novae; stellar systems, nebulae, galaxies, interstellar matter; geodesy and navigation. Books published and reviewed are also included.

VERSTAENDLICHE ELEMENTE DER WELLENMECHANIK. I Teil, *Karl Jellinek*, 1950, *Wepf & Co.*, Basel, Switzerland. 304 pages. 34 SFr.

An introduction to wave mechanics, addressed to experimental physicists and chemists, the book discusses the uncertainty principle; the duality of light and matter; and the simplest cases of the Schroedinger equation, including the hydrogen atom. The author attempts to retain the classical ideas of "particle" and "position," and manages to do so by introducing an appropriate kind of universal ether. The book is in German, and assumes a familiarity with calculus.

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Amateur Astronomers

THIS MONTH'S MEETINGS

Cambridge, Mass.: The Bond Astronomical Club will meet on Thursday, March 1st, at 8:15 p.m. at Harvard Observatory, when Dr. Carl A. Bauer, of the observatory, will speak on "Bode's Lost Planet."

Chicago, Ill.: The Burnham Astronomical Society will meet on Sunday, March 11th, 4:00 p.m. at the Adler Planetarium. Dr. Guy C. Omer, Jr., of the University of Chicago, will speak on "Cosmology — The Physics of the Universe."

Cleveland, Ohio: "The Magellanic Clouds" will be discussed by Dr. Harlow Shapley, Harvard College Observatory, at the March 9th meeting of the Cleveland Astronomical Society, 8:00 p.m. at the Warner and Swasey Observatory.

Columbus, Ohio: At the March 9th meeting of the Columbus Astronomical Society, held at McMillin Observatory at 8 o'clock, "Our Galaxy" will be discussed.

Dallas, Tex.: The film, Navigation and Nautical Astronomy, will be shown at the March 26th meeting of the Texas Astronomical Society. The meeting is in the community room of the Texas Bank and Trust Company at 8 o'clock.

Detroit, Mich.: On Sunday, March 11th, at 3:00 p.m., in State Hall, Wayne University, Dr. A. Keith Pierce, of the McMath-Hulbert Observatory, will speak on "The Internal Structure of the Earth and the Planets."

Geneva, Ill.: The Fox Valley Astronomical Society meets on Tuesday, March 6th, in the Geneva City Hall. Dr. Ben Hur Wilson, of Joliet Junior College, will speak on "The Earth as a Planet."

Greensboro, N. C.: At the March 14th meeting of the Greensboro Astronomy Club, in the science building of the Woman's College, 8:00 p.m., Miss Lila Peck Walker, of the college faculty, will speak on "Our Most Important Planet, the Earth."

Indianapolis, Ind.: "Wonders of Our Milky Way" will be the subject of Dr. Harry E. Crull, of Butler University, at the March 4th meeting of the Indiana Astronomical Society, 2:30 p.m. at Cropsey Hall, Riley Library.

Madison, Wis.: Professor Charles Curtiss, of the University of Wisconsin, will speak on "Atomic Structure and Energy Sources," at the March 14th meeting of the Madison Astronomical Society, 8 o'clock at Washburn Observatory.

Minneapolis, Minn.: At the meeting of the Minneapolis Astronomy Club on March 7th, 7:30 p.m. in the Library Science Museum, Dr. Strathmore R. B. Cooke, of the University of Minnesota school of mines, will speak on "The Moon."

New York, N. Y.: Mrs. Margaret W. Mayall, of Harvard College Observatory, will speak about "The AAVSO Organization and Activities," on March 7th at the meeting of the Amateur Astronomers Association, 8:00 p.m. in the American Museum of Natural History.

Sacramento, Calif.: The Sacramento Valley Astronomical Society will hold its sixth annual business meeting on March 20th at the Sacramento Junior College Little Theater at 8:00 p.m.

Washington, D. C.: The National Capital Astronomers will meet on Saturday, March 3rd, at 8:15 p.m. in the Commerce Building auditorium. Dr. Harlow Shapley, of Harvard College Observatory, will speak on "Problems of the Galaxies."

OHIO OPEN NIGHTS

The Warner and Swasey Observatory, in East Cleveland, has scheduled public nights for several Thursday and Friday evenings during the next three months, when lectures will be given at 8:00 p.m. Reservations may be made through the Case Institute of Technology, Tyler 1-1000. On March 15th and 16th the topic will be, "Measuring the Universe." On April 19th and 20th, "The Formation of Stars and Planets" will be discussed, and on May 17th and 18th the lecture will be about "The Summer Sky."

On the Ohio State University campus, the McMillin Observatory will hold public nights on the first and third Saturdays of each month. The subjects of the lectures will be: March 3rd and 17th, "The Sun and Other Stars"; April 7th and 21st, "Tales of Comets"; May 5th and 19th, "Our Neighboring Worlds." The series of open nights will continue through the year.

CENTRAL CONNECTICUT AMATEUR ASTRONOMERS

The newly organized Central Connecticut Amateur Astronomers is holding meetings at the Van Vleck Observatory, Wesleyan University, Middletown, on the first Tuesday of each month. At its January meeting the following officers were elected: William Hartke, Middletown, president; Roland B. Bourne, West Hartford, vice-president; Charles Brewer, Manchester, secretary-treasurer. Following each regular lecture, members will join either the observing section or the instruments section for the remainder of the evening. Section chairmen are Clinton B. Ford, Suffield, and Robert Hergstrom, New Britain, respectively.

Further information about this new society, which also expects to include a junior group from ages 12 to 16 in its membership, may be had from Mr. Brewer, at 4 Robin Rd., Manchester, Conn.

CHATTANOOGA OBSERVATORY

The Clarence T. Jones Observatory, on Brainerd Road in Chattanooga, Tenn., is open to the public every Friday evening, rain or shine, and observing with the 20½-inch Cassegrainian telescope is conducted when weather permits. The observatory, which is affiliated with the University of Chattanooga astronomical department, is also headquarters for meetings of the Barnard Astronomical Society, on the third Friday evening of the month.

GLEANINGS FOR ATM's

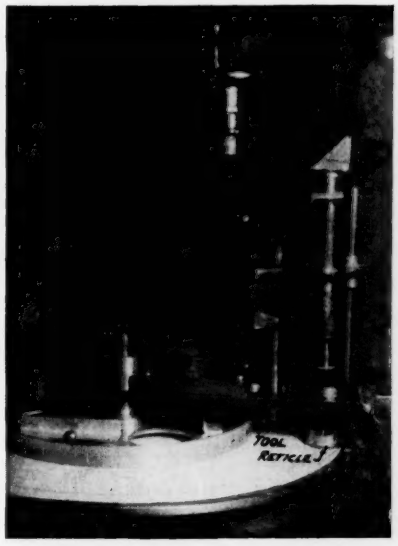
EDITED BY EARLE B. BROWN

Setting the Setting Circles

AFTER YEARS of struggling with shaky mountings that quivered at the slightest touch, I finally mounted my reflector on a cast-iron pipe sunk into the ground with concrete poured all around. I also provided it with setting circles which I divided with the homemade machine that is illustrated here.

This machine simply transfers the divisions from a 14-inch protractor with ¼° divisions, pasted to the large iron base, to the circle being divided. The protractor appears all white in the picture, but the divisions on the circle may be seen. The reticle is used to sight on each of the protractor divisions by means of the telescope at the top of which is a totally reflecting prism to give a horizontal view.

My circles are not finely divided. The declination circle reads from 0° to 90° on each side of the equator by ½° divisions, and it is easy to estimate to tenths of a degree. The right-ascension circle, reading from 0 to 24 hours, is divided to two minutes of time, which is close enough to locate any object in the finder or in the main telescope using a low-power eyepiece. But it is not attached to the polar axis except for each night's work. An hour circle permanently mounted requires a continuous knowledge of the sidereal time and is not as convenient as a right-ascension circle that may be locked to the telescope driving clock at will. With the slip circle you direct your telescope at the beginning of observations to some prominent star whose right ascension you know; you set your circle to this right ascension and clamp it on the driving clock shaft or clutch. Thereafter, you can set your telescope to the hour angle of the object sought by locating its right ascension on the circle. Your driving clock is your sidereal clock.

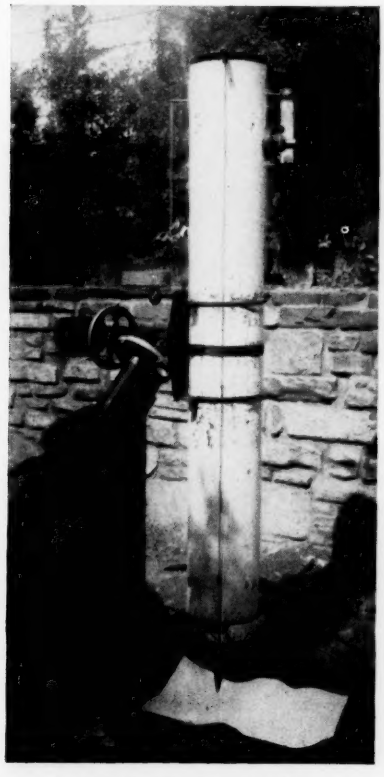


A machine for ruling setting circles, built at home by Juan J. Ruiz.

I made sure the declination axis of the mounting was truly at right angles to the polar axis using the method outlined by Allyn J. Thompson on page 144 of his book, **Making Your Own Telescope.** I then proceeded to set the circles following the instructions given many years ago by Schaeberle, Lick Observatory astronomer, and included in W. W. Campbell's book on practical astronomy, which I believe is now out of print, so perhaps it would be worthwhile to repeat these instructions here.

Of course, my mounting can be adjusted on the pier in both elevation and azimuth. First I made a preliminary adjustment in azimuth, using a compass and the known magnetic declination of the needle for my locality. I could have done this by sighting Polaris near its culmination above or below the pole. The polar axis was then elevated to an angle equal to the latitude of the place, which I obtained with sufficient accuracy from a Geological Survey map. I used a protractor and a good machinist's level for this purpose.

On the open end of the reflector tube, I fastened a metal strap extending a few inches beyond the telescope tube. A small hole was drilled in this strap a couple of inches from the tube, and a plumb line threaded through and fastened. At the mirror end of the tube, another metal strap was clamped and a small hole drilled as nearly opposite to the other hole as could be judged, so that the plumb line



The plumb-line method of adjusting the polar axis and setting the circles.

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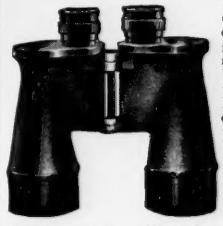

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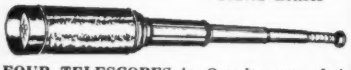

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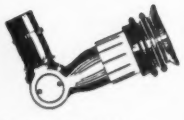

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would stretch parallel to the optical axis when the telescope was directed to the zenith. Absolute parallelism is not necessary, but convenient.

To damp its oscillations, the plumb bob was let swing in a can of water, but this can is not shown in the accompanying photograph of the arrangement. Using the slow motions on the mounting, I carefully centered the plumb line in the lower hole. The circle readings were taken and recorded. Then the telescope was swung through 180° to the other side of the pier and again set so the line was adjusted centrally in the lower hole. The circles were again read and averaged with the first set of readings.

The average of the hour angle readings is the reading when the telescope is on the meridian and should be 0^h 0^m, or 24^h; the average of the declination circle readings is the elevation of the polar axis and should therefore be equal to the latitude of the place. On my first trial I obtained for the declination with the telescope east of the pier 44° 45′, and 45° 15′ with it west of the pier. As the latitude is 44° 43′, this showed that my polar axis was elevated 17 minutes of arc too high. The right-ascension circle readings were, respectively, 24^h $1^m.0$ and 24^h $2^m.0$, for an average of 24^h $1^m.5$.

With the telescope still west of the pier, the tube was moved until the declination read 44° 58′ (as nearly as I could judge) and the elevation of the polar axis was changed until the plumb line was again centered on the lower hole. The index on the right-ascension circle was moved 1.5 minutes toward the 24-hour mark. A second trial gave average readings of 24^h $0^m.0$ and 44° 45′, which was close enough to my latitude, and I left it there.

It now remained to adjust the polar axis in azimuth. One way of doing this is described in **Making Your Own Telescope** on page 162, based on observations of Polaris, and another way on page 167, based on noontime observations of the sun.

JUAN J. RUIZ
P. O. Box 115
Dannemora, N. Y.

A Large Planetary Reflector

THERE comes a time when most amateurs desire a reflector of large aperture and long focus, equipped with a convenient clock drive. Such an instrument is particularly advantageous for observing lunar and planetary detail, because of its long focal ratio and high resolving and light-gathering power.

The writer, after using smaller reflectors for planetary and lunar work for a number of years, decided that an aperture of 12½ inches, with a focal length of 10 feet, would make about the largest telescope that could be conveniently used and handled by an amateur observer. I did the grinding of the 12½-inch pyrex blank, and the polishing and figuring was done in the shops of the Herron Optical Co. in Los Angeles, where I am employed. This finishing portion of the optical work was carried out with the great assistance of J. H. Herron and Avery Hildom. The final figure of the mirror has proven excellent. An elliptical pyrex diagonal mirror of 2-inch minor axis is used to deflect the light beam to the eyepiece.

The mounting was built in about two months time by the writer and his father. A sheet-metal shop formed the round aluminum tube, which is 10¼ feet in length and 15 inches in diameter. Heavy bronze reinforcing rings for the ends of the tube were turned by a machinist. A large door was cut in the end of the tube just above the mirror cell, for access to the mirror. The spider is of brass of the three-arm variety, and very rigid. A smoothly operating rack-and-pinion ocular focusing device is used. The finder is constructed of a 2½-inch objective lens of 15 inches focal length and a surplus eyepiece and prism, placing the finder eyepiece close to the rack and pinion.

The English double yoke mounting was selected first for rigidity, and second because the framework of the telescope was mounted on wheels to make it portable. The yoke and framework of the telescope were made of selected 2 x 4's and 2 x 6's hard pine. The declination axes were made of heavy pipe, but since a good clock drive was of prime importance, heavy roller bearings and solid shafting 2½ inches in diameter were used in the polar axis.

It was desirable to rotate the tube, since its length might otherwise often place the observer in an awkward position. A heavy saddle was constructed by sawing circles 2½ inches thick from laminated plywood, joining these rings by 2 x 4's 30 inches in length. Within each of these rings six roller skate wheels were installed, and on these the tube turns.

A friction clutch on the polar axis for the clock drive was constructed by George Schmid, of Los Angeles, to eliminate the

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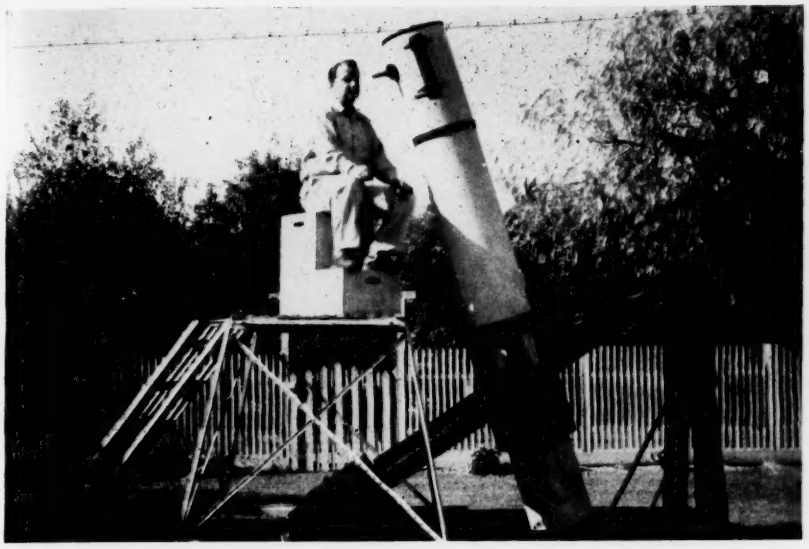

Thomas R. Cave, Jr., on the observing stand of his 12½-inch reflecting telescope of 121 inches focal length. The mounting is of wood, clock driven, and may be moved about on wheels.

need for clamps and allow the telescope to turn freely without disengaging the worm gear. The scope is easily driven by a little 1-r.p.m. Leach synchronous motor delivering 40 inch-ounces of torque. The drive has proven smooth, and the telescope is free from vibration. Through a 380x eyepiece, a planet or star will remain in the field for more than an hour when proper polar alignment is obtained.

Our three-by-five-foot observing platform was made of heavy aluminum posts and bracings and a top of wooden slats. The stand is very firm and stable, capable of sustaining two persons safely and conveniently. Two six-inch wooden wheels on the front of the platform enable it to be moved into position with ease. The ladder is in reality a series of five stairsteps built between aluminum sides, the steps covered with rubber to prevent slipping, and the ladder hooking onto the stand. The seat is a box giving three elevations, and it may be moved about on the platform, enabling the observer to follow a planet for an hour or more without moving the platform.

In performance, both optical and mechanical, the instrument has exceeded expectations. The telescope, although only in use a few months, has revealed a wealth of very fine belt detail on Jupiter, and craterlets on the floor of Plato invisible in an excellent 8-inch reflector. Only a few close "test double stars" have been observed; however, two equally bright stars of the 6th magnitude, one-half second of arc apart, have been cleanly separated. On open clusters, nebulae, and rich-field objects the large scope is at a decided disadvantage, but on the moon and planets its performance leaves little to be desired. This new telescope will be used in a regular program of observations of Mars, Jupiter, and surface detail on Ganymede, as well as for work on Saturn. Some lunar observing will also undoubtedly be undertaken.

The writer hopes other amateurs will construct telescopes of similar aperture and focal length. Such a scope will reveal detail on the planets beyond the reach of instruments that are smaller and of shorter focus.

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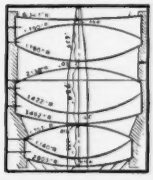

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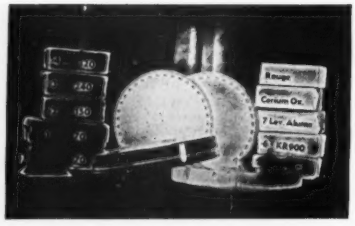

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Visual Observing Programs for Amateurs — XII

Variable Star Observing — (continued)

3. Estimating the brightness of a variable. As the preceding description of how to find a variable star implies, each AAVSO chart contains its own magnitude scale. Near the variable are comparison stars whose brightnesses have been carefully determined, and they are used as a scale. When we identified T Cephei in the sky (see the January issue), we did so using its orientation with regard to stars marked 105, 101, and so on, meaning that these stars are of magnitude 10.5, 10.1, and so on, respectively.

As we look at T Cephei through our telescope, and check it with the AAVSO "d" chart (reproduced on page 73 of the January issue), we ask ourselves, "Is it brighter than 105?" "Yes." "Than 101?" "Possibly." "Than 81?" "No, it is quite definitely fainter than 81." At this point we search our chart for other comparison stars and find 96 not far away. T is definitely fainter than 96, but after careful review we believe it is brighter than 101. Hence, we estimate it at 98 magnitude, for it seems nearer to 96 than to 101.

We jot this observation down on our log sheet, together with the time and date, and our first variable star observation is made!

Now the logical question confronts us: Suppose instead of being faint, at 98 magnitude, T Cephei had turned out to be quite bright, what then would we have done for comparison stars? The AAVSO issues several different types of charts. In our example we have been using both the "b" and the "d" chart. The "b" charts are most useful with a 3- to 6-inch telescope with low power, not exceeding 40x, and a wide field of upwards of a degree. The T Cephei "b" chart shows comparison stars to magnitude 111. The "d" chart is more useful when the star is faint and with 4-inch or larger telescopes, using powers of 40 and higher. The T Cephei "d" chart shows comparison stars to 129 magnitude. But if the star is bright, say above 65 magnitude, we shall need to use an "a" chart, which shows some 30 degrees of the sky each way, and comparison stars down to 74 magnitude. This "a" chart is erect, as one sees the sky by eye or binocular, and if T Cephei is bright, we shall need to use either our wide-angle finder or a binocular to compare its brightness with such comparison stars as 49, 54, 55, and 60 magnitude, all located some five or six degrees away from T Cephei. It will be difficult if not hopeless to use our main telescope for comparison purposes when T is above 67 magnitude, for if we have to hunt up comparison stars several degrees away we will inevitably lose track of T Cephei itself.

How will you know which chart is appropriate? Usually by finding the star and learning whether it is bright or faint and then choosing the chart which works best. After you get in the swing of things and become a regular contributor of observations to the AAVSO, you will receive a bimonthly bulletin as a guide to the probable current brightness range of each AAVSO variable.

Sometimes one will find it impossible to estimate the brightness of a variable star. I have seen 213843 SS Cygni a number of times when it has seemed both brighter than 113 and fainter than 118. Other observers tell me that they occasionally have this trouble with certain other stars. Of course, this abnormal condition only arises occasionally — usually the comparison stars in the SS Cygni field are all in order.

Sometimes the atmosphere is so jumpy that stars will appear to vary erratically in brightness and no estimate is possible. Such a condition occurs in New England about once a year during a cold wave.

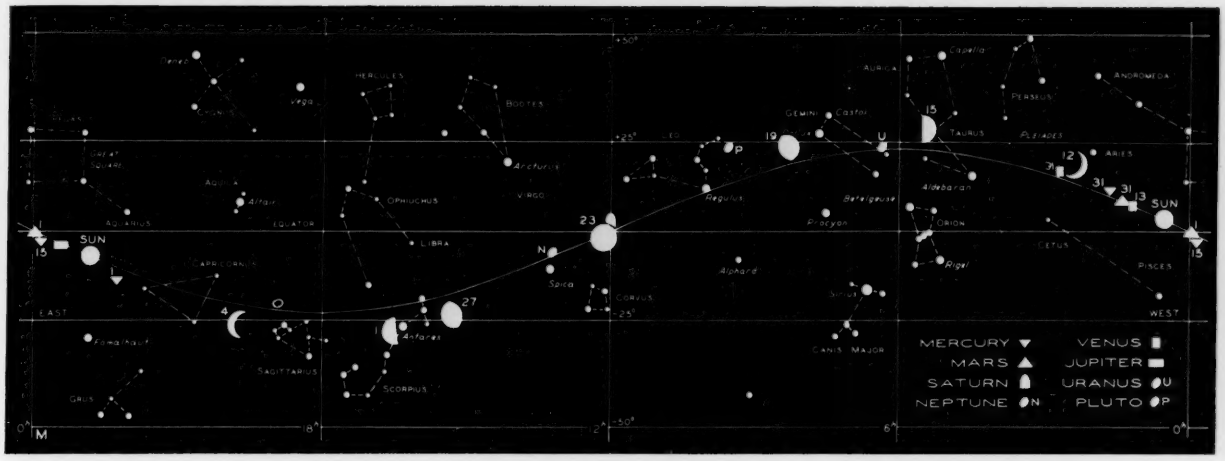
Red stars are very troublesome. As one gazes at them they seem to rush upwards in brightness, a half magnitude or more. This is due to the physiological phenomenon called the Purkinje effect. To counteract it, try looking quickly at the stars and then away — the "quick glance" method.

Sometimes the comparison stars marked on an AAVSO chart will seem improperly labeled every time one looks at the field. A 76 star may seem permanently brighter than a 72 star. This may be due to idiosyncrasies in either your eye or that of the original determiner of the magnitudes. In such a case decide which star, the 72 or the 76, is apparently in error and do not use it in future estimates.

As in the case of finding a variable star, we must not suppose that estimating its brightness is an easy process at first. When I started the work, I sometimes took as long as 20 minutes determining the magnitude of a variable. Nowadays, even with a strange star, I would not take over a minute, for I am of the opinion that confident first impressions are more accurate than doubting second impressions, because the eye soon tires. Beginners should start with comparison stars which are very definitely brighter and fainter than the variable star in question and move in on it from both directions. As Sir William Herschel pointed out long ago, "If one cannot decide which of two stars is the brighter, then they are equal."

4. Organizing a variable star program. Members of the American Association of Variable Star Observers can secure a chart catalogue from Richard W. Hamilton, AAVSO chart curator, 4 Union Park, Norwalk, Conn. From this they can select charts covering suitable stars for their own conditions, giving due regard to the part of the sky that is seen best, the faintest stars visible in available instruments, and the time of year observing is begun.

It will be noted that variable stars tend to congregate along the Milky Way; indeed, it is sometimes considered that the study of variable stars is essentially a study of Milky Way evolutionary and



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown.

distance problems. There are two periods of the year when variable stars present themselves in great profusion, let us say September and October, and February and March, when the Milky Way is overhead at dusk. At other times of the year, the sky presents fewer variable stars, at least for the amateur who must do his observing in the early evening hours.

Some observers like to keep their charts filed by constellations, but I use 48 folders. In the first are charts numbered 000451 to 001909, in the second those numbered 003179 to 005840, that is, by half hours of right ascension. A wooden wedge may temporarily take the place of a chart which is in use at the telescope; this facilitates refiling. It is convenient to paste the finder charts on the backs of the larger comparison charts; the "d" charts are best for this purpose.

To record your observations use either a ledger sheet for each star, or enter all observations serially on a nightly log sheet. The ledger system permits easier completion of the monthly report in which all observations of a star are grouped together, and it permits easier plotting of light curves if one feels so disposed. The log system may result in more accurate observations, for the observer will not have noticed (on a ledger sheet) how bright a star was the last time it was observed. The log system is speedier on nights when observing is good; it is better to leave desk work to cloudy nights.

At the telescope, use a flashlight small enough to be held in your teeth. I prefer the "C" cell size. You can cover the lens with red paper or cellophane to decrease glare on the charts.

If your telescope has setting circles, they may be of limited use, even if the instrument is not set up in permanent alignment. For instance, you may determine beforehand that T Cephei is about 20 minutes west and two degrees south of Beta Cephei. Point the instrument at Beta Cephei and move it by the above amounts; then it cannot be far from pointing at T Cephei. However, by the time you have done this, T Cephei may have moved on and you may decide to revert to the old reliable method described heretofore, using the AAVSO charts or their equivalent.

The bimonthly prediction list for the ensuing two months will enable you to plan your observing with stars of suitable brightness and to choose the most suitable charts before going to the telescope. If there is moonlight, work on brighter stars; if the night is very clear and dark, concentrate on faint stars.

Seek to add to your repertoire of variable stars as time goes on. It is probably not desirable to develop pets as I have done, and which I may observe more than necessary. Strive for not more than three observations per month on each of 30 long-period stars, rather than for 10 observations on only nine of them.

DAVID W. ROSEBRUGH
79 Waterville St.
Waterbury 10, Conn.

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.

The sun will be in annular eclipse on March 7th, visible in partial phases in the United States. See the article on page 102, February issue, for details.

Mercury enters the evening sky on March 11th, passing superior conjunction with the sun. By the last week of the month the planet attains a favorable position for observation, setting 1½ hours after the sun and appearing at magnitude −1. Mercury is at perihelion on March 27th and at greatest elongation on April 5th, 19° east of the sun.

Venus continues its motion away from the sun, appearing as a brilliant evening star, setting two hours or more after sunset. About the middle of the month Venus will be seen 87 per cent illuminated, with a disk 12 seconds of arc in diameter, when viewed telescopically.

Earth arrives at heliocentric longitude 180° on March 21st at 10:26 UT. Spring begins in the Northern Hemisphere and autumn south of the equator, with day and night approximately equal over the earth.

Mars and **Jupiter** will not be observable during March due to their nearness to the sun. Mars remains east of the sun, while Jupiter enters the morning sky on the 11th.

Saturn comes to opposition with the sun on March 20th, 788,600,000 miles from the earth. The stellar magnitude is +0.8, not too bright, for the rings are quite narrow and they contribute little to the total brightness of the planet. The rings are now inclined only 2½° to our line of sight, with the north face visible.

Uranus remains in a favorable position for observing during evening hours. Eastern quadrature with the sun is attained on March 26th. Use the chart in the February issue, page 103, to locate Uranus with opera glasses, 1° northeast of Mu Geminorum and nearly stationary all month.

On March 13, 1781, just 170 years ago, Sir William Herschel, one of the greatest observers of all time, first saw Uranus. The planet is within a few degrees of where it was discovered; it has made a little over two revolutions since that time.

Neptune will be above the horizon most of the night, for opposition occurs on April 8th. Good binoculars will be needed to view the planet, as it is of the 8th magnitude. See the February issue for a chart of its position. E. O.

MINIMA OF ALGOL

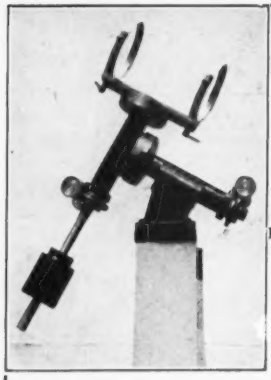
March 2, 4:48; 5, 1:38; 7, 22:27; 10, 19:16; 13, 16:06; 16, 12:55; 19, 9:44; 22, 6:33; 25, 3:22; 28, 0:12; 30, 21:01. April 2, 17:50; 5, 14:39.

These predictions are geocentric (corrected for the equation of light), based on observations made in 1947. See **Sky and Telescope**, Vol. VII, page 260, August, 1948, for further explanation.

PHASES OF THE MOON

New moon	March	7, 20:50
First quarter	March	15, 17:40
Full moon	March	23, 10:50
Last quarter	March	30, 5:35
New moon	April	6, 10:52

	March	Distance	Diameter
Perigee	2, 7h	229,800 mi.	32′ 19″
Apogee	15, 6h	251,200 mi.	29′ 33″
Perigee	27, 9h	228,600 mi.	32′ 30″



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PREDICTIONS OF BRIGHT ASTEROID POSITIONS

No. 9	Metis		Mag. 9.3	
	h	m	°	′
Mar. 15	13	45.5	−3	08
25	13	38.5	−2	24
Apr. 4	13	29.7	−1	38
14	13	20.0	−0	54
24	13	10.7	−0	20
May 4	13	02.6	−0	01
No. 44	**Nysa**		**Mag. 9.5**	
	h	m	°	′
Mar. 15	13	30.7	−3	49
25	13	23.8	−2	47
Apr. 4	13	15.2	−1	40
14	13	06.2	−0	38
24	12	57.9	+0	12
May 4	12	51.4	+0	44

The above are predicted positions in right ascension and declination for the epoch 1951.0, for 0h Universal time. The magnitude is that expected at opposition. In each case the motion of the asteroid is retrograde.

OCCULTATION PREDICTIONS

March 9-10 **Delta Piscium** 4.6, 0:46.1 +7-19.1, 2, Im: **C** 23:21.7 −0.5 +1.2 26; **D** 23:29.8 −0.4 +3.2 0; **E** 23:15.3 −0.6 +2.2 13; **F** 22:55.3 −1.2 +1.2 41. Em: **C** 0:13.3 −0.2 −1.7 278; **E** 0:03.8 −0.9 −2.3 284; **F** 0:07.7 −1.0 −0.3 251.

March 18-19 **Gamma Cancri** 4.7, 8:40.5 +21-38.8, 11, Im: **E** 6:35.4 ... ... 57; **F** 6:29.7 −1.5 −1.3 99; **G** 5:42.6 −2.0 −0.1 77; **H** 5:47.3 −1.6 −2.0 129; **I** 5:25.8 −1.8 −0.4 95. Em: **E** 7:05.5 ... ... 3; **F** 7:33.7 0.0 −2.3 325; **H** 7:09.1 −1.4 −1.8 296.

For standard stations in the United States and Canada, for stars of magnitude 5.0 or brighter, data from the **American Ephemeris** and the **British Nautical Almanac** are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, **UT**, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computations of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo** — **LoS**), and multiply **b** by the difference in latitude (**L** — **LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5, +42°.5	**E**	+91°.0, +40°.0
B	+73°.6, +45°.6	**F**	+98°.0, +31°.0
C	+77°.1, +38°.9	**G**	+114°.0, +50°.9
D	+79°.4, +43°.7	**H**	+120°.0, +36°.0
		I	+123°.1, +49°.5

VARIABLE STAR MAXIMA

March 2, U Orionis, 6.6, 054920a; 2, R Geminorum, 7.1, 070122a; 12, R Draconis, 7.6, 163266; 15, T Normae, 7.4, 153654; 17, RU Sagittarii, 7.2, 195142; 18, R Pegasi, 7.9, 230110; 26, R Horologii, 6.0, 025050; 29, R Trianguli, 6.3, 023133. April 3, X Monocerotis, 7.6, 065208; 3, R Canum Venaticorum, 7.7, 134440a; 4, R Cancri, 6.8, 081112.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the predicted magnitude, and the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern).

DEEP-SKY WONDERS

THE FAMOUS PRAESEPE, M44, NGC 2632, at 8h 37m.2, +20° 10′ (1950), has a diameter of 90 minutes of arc. While too large for big telescopes, it is a brilliant show object in low-power fields, finders, and binoculars. Smyth's words bear revival:

"The Praesepe, metaphorically rendered Bee-hive, is an aggregation of small stars which has long borne the name of a nebula, its components not being separately distinguishable by the naked eye; indeed, before the invention of the telescope, it was the only recognised one, for though that in Andromeda must have been seen, it attracted but little notice till the days of Simon Marius, in 1612. Whereas the Praesepe in Cancer engaged very early speculation; insomuch that both Aratus and Theophrastus tell us, that its dimness and disappearance during the progressive condensation of the atmosphere, were regarded as the first sign of approaching rain. The group is rather scanty in numbers, but splendid from the comparative magnitude of its constituents, which renders it a capital object for trying the light of a telescope. Yet Galileo discovered this cluster to consist of 36 small stars, when it was supposed that there were only three **nebulous** stars, which emitted the peculiar light." This was published in 1844, but with the timelessness of celestial splendors, Smyth's words are as interesting today as when they were written over a century ago.

WALTER SCOTT HOUSTON

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NORTON'S "Star Atlas and Reference Handbook," latest edition, 1950, $5.25 postpaid. "Atlas Celeste," International Astronomical Union's official atlas to magnitude 6.0, $2.55. "Bonner Durchmusterung" still in print; ask for information. Herbert A. Luft, 42-10 82nd St., Elmhurst, N. Y.

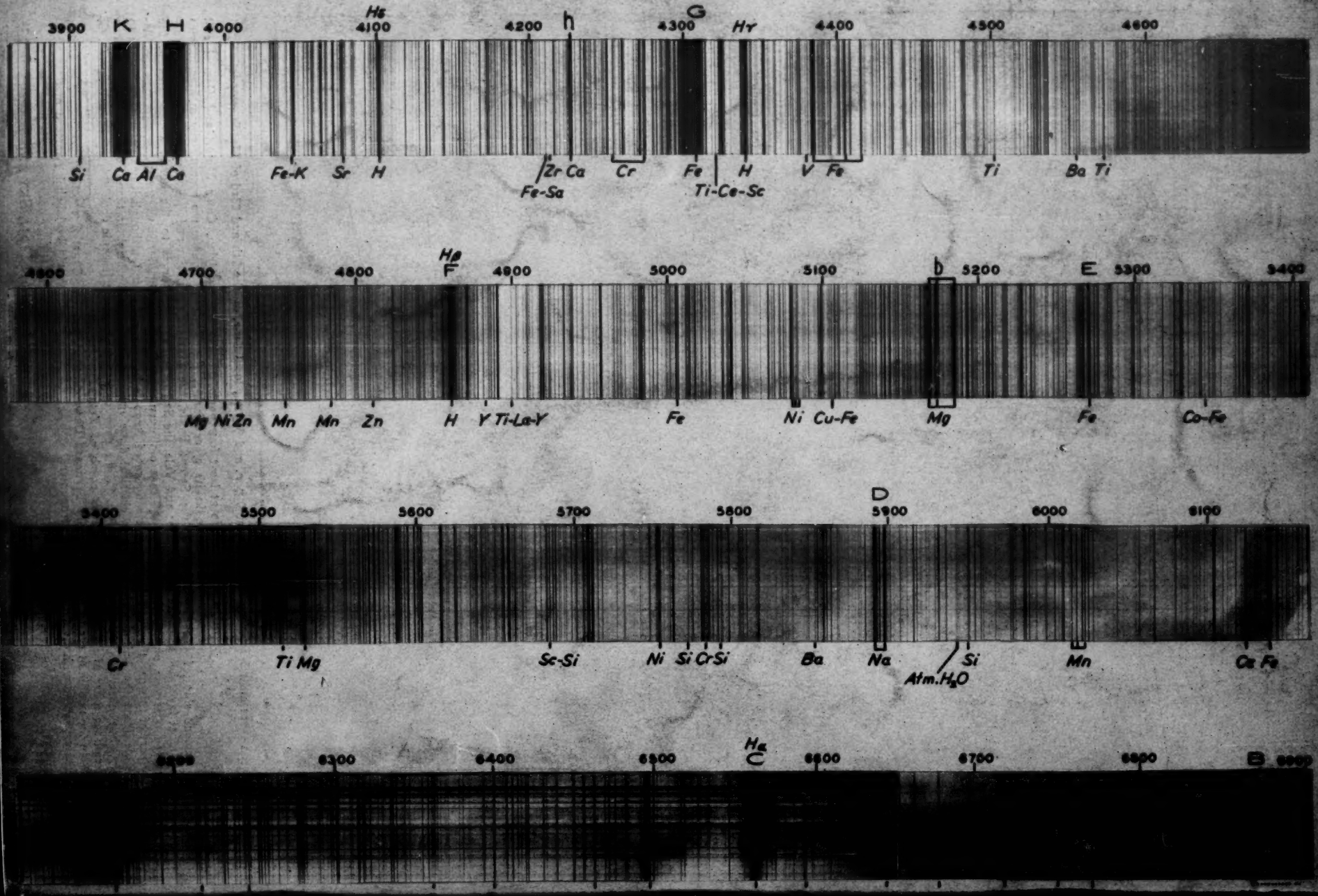
The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of March, respectively.

STARS FOR MARCH

ARGO, the ancient ship of the sky, stands in its most favorable place for sharp-eyed northern observers on March evenings. Only part of this one-time constellation is visible from the latitude of New York City, but observers in the southern states can see more of its great extent. Lacaille, in the middle of the 18th century, is generally credited with dividing Argo into at least four parts. Today we recognize in its place Carina, the Keel; Puppis, the Stern; Pyxis, the Mariner's Compass; and Vela, the Sails.

As in the case of Taurus and Pegasus, a complete figure of Argo is usually not shown in classical drawings. In November, 1942, a bright nova appeared about five degrees north of Zeta Puppis, discovered by Bernhard Dawson, an Argentinian astronomer.

Orion, Canis Major, and Gemini still dominate the evening sky in March, with Castor and Pollux near the meridian. Castor is to the north, and Pollux is the brighter. Castor is Alpha in the constellation, although it has never been known to be brighter than Pollux. It is a famous telescopic double. O. G.

Chart Correction: Bellatrix, in Orion, should be labeled γ instead of β.

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